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Translation, psycholinguistics
and cognition
Agnieszka Chmiel

12.1 Introduction
In order to study cognitive processes involved in translation, it is natural to draw upon psychology and cognitive science. In fact, according to Munday (2001), these two play a leading role in the study of the process of translation and interpreting. Psycholinguistics, an area at the intersection of psychology and language, is featured on the level of areas of linguistics relevant to translation, according to Snell-Hornby’s integrated approach to translation (1988).

Psycholinguistics has developed since the mid-1960s (Traxler & Gernsbacher, 2011) and focuses on psychological mechanisms of linguistic processing. It tries to explain how language is processed by the human mind and includes such areas as spoken and written language comprehension and production. Traditionally, psycholinguists have been interested in discovering the psychology of language in a monolingual individual. However, since the majority of people are currently bilingual, a lot of psycholinguistic research is conducted in the area of bilingualism and multilingualism (Bialystok et al., 2012). Another interesting population for psycholinguists to study is code-switchers, i.e. bilinguals who frequently mix their two languages (Verreyt et al., 2015). It is thus a natural extension to also look into the population of translators and interpreters, who use their languages in very specific circumstances, which might impact the way their minds process languages. As Dijkstra et al. (2018, p. 17) claim when discussing translation: “although every bilingual from a young child to a professional interpreter can to some extent perform this task, it is one of the most complex language activities that a human speaker can engage in”.

Historically, Translation Studies embraced psycholinguistics as one of the sources of interdisciplinarity in the mid-1980s with the start of translation process research (TPR) (Alves, 2015) and the empirical turn (Snell-Hornby, 2006), when experimental research on translation and interpreting gained impetus. In fact, studies by Krings and Lörscher with the application of think-aloud protocols (TAPs) were deemed “the first highly visible contribution of psychology to research into written translation” (Ferreira et al., 2015, p. 5).

Krings (1986) used the method of think-aloud protocols and asked his participants to think aloud and verbalize their thoughts while translating. The idea, borrowed from psychology, was to get an insight into the black box of the translator’s mind and examine word choice decision processes. The premise was that such data could be interpreted as observable indicators of
unobservable mental processes (Lörscher, 1996). The same method was later used by Jääskeläinen (1989), Tirkkonen-Condit (1989) and Lörscher (1991), bringing consistent accounts of different approaches to translation used by professionals and non-professionals. While the former used their background knowledge, analysed the text holistically and focused on the sense, the latter focused more narrowly on words and phrases. Concurrent TAPs were later criticized for their limited value, as verbalizations could interfere with the cognitive process under scrutiny (Jakobsen, 2003).

The application of TAPs in the study of the translation process gave way to TPR, which is a very dynamic trend in Translation Studies. It focuses on unveiling the complexities and intricacies of the translation process. It has now an almost 30-year-long history (Alves, 2015), and psycholinguistics, alongside cognitive studies, expertise studies and neuroscience, is one of the major neighbouring disciplines influencing it. TPR uses “a behavioural-cognitive experimental methodological paradigm” (Jakobsen, 2017, p. 21). Jakobsen (2017) claims that TPR and psycholinguistics share the same assumption of the mind–brain–behaviour correlation: in other words, by observing certain behaviours (such as keylogging, eye movements or brain activity) we can make inferences about processes in the translator’s black box.

Although TPR has been “greatly inspired by the methodological rigor of cognitive psychology and experimental psycholinguistics” (Jakobsen, 2017, p. 23) with highly controlled variables, translation process researchers still focus on ecological validity and making experimental conditions as similar to the authentic translation task as possible. According to Alves (2015, p. 30), “[a]ssuring a reasonable level of ecological validity for the translation task under investigation is a major problem in terms of developing a rigorous experimental design with controlled variables”. The current strategy is to sacrifice some experimental control for the sake of ecological validity and to offset less strictly controlled conditions and more numerous confounding variables with more advanced statistical methods that can to a certain extent control these confounds (such as linear mixed models) (Jakobsen, 2017).

There are two potential solutions to the problem: either benefit from Big Data advantages by using corpus-based data and confirm the results by running a psycholinguistic experiment (e.g. Hansen-Schirra’s studies on nominalizations and cognates: Hansen-Schirra, 2011; Hansen-Schirra et al., 2017—see also Hansen-Schirra & Nitzke, this volume) or use an approach that seems a fair compromise between experimental control and ecological validity. This approach involves using constructed rather than authentic texts in experiments so that the texts include appropriately controlled and distributed experimental items. Such a method of creating experimental material has been applied, for instance by Jensen et al. (2009) and Balling et al. (2014) in a study of written translation and by Chmiel and Mazur (2013) in their eye-tracking experiment on sight translation. In such a setup, experimental participants work with a text, so that the task seems authentic to the participant (except for other experiment-related circumstances, such as location, presence of the experimenter, or the eye calibration procedure necessary to record eye movements). However, the text used may be manipulated so that it includes neatly distributed and strictly controlled, matched and normed experimental stimuli (words or sentences). Thus, what appears to the participant to be a single text to be interpreted is in fact a series of experimental trials combined within one text. Obviously, certain confounding variables are still present. For example, spill-over effects due to a troublesome sentence located prior to the experimental stimulus might still skew the data. However, experimental stimuli in such a design are much more controlled than in an authentic text.

TPR scholars have frequently adopted the method of data triangulation (Alves, 2003), that is, combining data obtained via different tools from the same translation or interpreting event to shed more light on the translation process. It is now standard practice to combine keylogging
with eye tracking and retrospective verbal reports. TPR provides useful information about reading and typing patterns in translation, lexical and syntactic processing and directionality. These core topics will be reviewed in the following sections.

It was interpreting scholars who welcomed influences from psycholinguistics in their research earlier than researchers on written translation. Psychologists became “intrigued by simultaneous interpreting as a challenge to prevailing theories on the limits of human processing capacity”, and psycholinguists “seized upon simultaneous interpreting as a means of testing their hypotheses concerning the role of input segmentation as well as hesitations and pauses in speech production” (Pöchhacker & Shlesinger, 2002, p. 25). Eva Paneth, a practising interpreter, wrote the first study (her MA thesis) combining interpreting and psycholinguistics (1957/2002). It was based on empirical data collected while observing interpreters at work during conferences.

Many scholars following Paneth focused on temporal aspects of processing in simultaneous interpreting, such as the delay between the source text and the target text, later known as ear-voice span (EVS) (Goldman-Eisler, 1972; Oléron & Nanpon, 1965). Gerver’s 1971 doctoral dissertation was deemed “the most comprehensive and influential piece of psychological investigation into simultaneous interpreting” (Pöchhacker & Shlesinger, 2002, p. 26), triggering many further experimental studies. Chernov’s (1979) work on semantic aspects of interpreting also contributed to this early cross-fertilization between interpreting and psycholinguistics. According to Chernov, information processing and comprehension in simultaneous interpreting are supported by anticipating sound patterns, semantic and syntactic structures, and the overall sense.

The relation between interpreting and psycholinguistics has not always been very close, and certain models of interpreting were based on intuition rather than insights from psychology (e.g. Gile’s effort models (2009)). In fact, as Gile (2015a, p. 46) himself points out, his models “were developed intuitively first and findings from cognitive psychology were gradually integrated into them as he discovered relevant work in that discipline”.

More recently, the need for combining psycholinguistics with interpreting studies has been re-emphasized (Chmiel, 2010; Gile, 2015b). Chmiel (2010) points to a potential synergistic effect and argues that the interaction between the two disciplines can be a two-way street mutually beneficial to both fields. Interpreting scholars have drawn upon memory and mental lexicon models and have applied experimental methodology developed by psycholinguists in their research. The main contribution of interpreting studies to psycholinguistics is the population of interpreters who, due to the extreme temporal constraints and extreme cognitive load involved in interpreting, have to exercise extreme language control (Hervais-Adelman et al., 2015). For instance, “interpreters may prove extremely useful in studies on the structure and flexibility of the mental lexicon” (Chmiel, 2010, p. 229). Moreover, by examining trainees throughout their training in a longitudinal study (in which their performance in experimental tasks is compared pre- and post-training), useful insights might be generated about how training influences linguistic processing and memory. By comparing interpreters working only into their first language (L1) with bi-directional interpreters (working both into L1 and into L2), we can learn about how directionality shapes the structure of the mental lexicon.

However, there are numerous problems related to conducting highly controlled experimental studies. Gile (2015a) mentions small experimental samples and difficult access to professional interpreters, who are often unwilling to participate in research (which may lead to underpowered studies, i.e. experiments too weak to find an expected effect), high dropout rates when recruiting trainees in longitudinal studies, the choice of dependent variables (for instance, it might be difficult to establish one accurate translation for a given word) and ecological validity (translating single words is hardly comparable to an authentic communicative act at a conference). Some of these problems may be overcome; for instance, experimental samples may be
increased by remunerating interpreters for their time in the laboratory and collecting longitudinal data from groups in two or three consecutive years to make sure the number of participants is high.

12.2 Core topics

The following sections present some core issues at the interface of translation, cognition and psycholinguistics. As the reader will notice, some of them have been examined more in a particular type of translation, while some have been tackled equally across written translation and interpreting. We also include (where relevant) a brief overview of studies in audiovisual translation and media accessibility (audio description and respeaking). This overview is by no means exhaustive but serves as a comprehensive survey of the interaction of translation, cognition and psycholinguistics.

12.2.1 Lexical processing

Words are the main tool used in translation, so lexical processing has been an object of study in psycholinguistic and process-oriented Translation Studies. Obviously, translation is much more than replacing words of the source language with those of the target language. However, such studies are part of incremental research and may tell us something about how words are processed in the translator’s mind at a basic level.

Because translation equivalents co-occur frequently in translation practice, direct memory associations may be formed between them, and “the more often the same two terms (words or longer phrases) co-occur in a translation act, the stronger the memory connection between them will be” (de Groot & Christoffels, 2006, p. 198). Translators have to actively engage in language control: activation and inhibition (Paradis, 1984). However, such language control differs from that exercised by regular bilinguals. Non-switching bilinguals may simply inhibit one language, while translators have to activate comprehension in the source language and production in the target language (Paradis, 1994). According to the monitor model, literal translation equivalents are selected unless there is a problem and other solutions have to be adopted (Tirkkonen-Condit, 2005). In the following, we present selected lexical processing studies pertaining first to comprehension and then to production. Many of these studies involve interpreters and not written translators, but, according to García et al. (2014), linguistic effects of translation experience may be independent of whether the experience pertains to interpreting or written translation.

Comprehension studies involve various research methods, such as self-paced reading (where participants read each word of a sentence separately and control when to see the next word), error detection, lexical decision (participants decide whether a string of letters is a word or not) and semantic decision (participants decide whether two words are semantically similar). Interpreters generally do not outperform trainees and controls in basic single-word-level comprehension, as has been shown by Bajo et al. (2000), but interpreting experience influences more complex processing such as detection of semantic errors (Morales, Yudes, et al., 2015), semantic categorization (Bajo et al., 2000) and recognition of semantic congruence (Elmer et al., 2010).

As regards production studies, García et al. (2014) found an effect of training but no effect of experience in a word translation task performed by translators and trainees. These findings were interpreted as follows: early training, when the focus is on interlinguistic associations, strengthens links between translation equivalents. These become so strong that further translation practice has no effect on them. In a study by Christoffels et al. (2006), interpreters outperformed non-interpreting students but not English teachers in a picture naming task, suggesting that not
only interpreting experience, but also other types of practice involving proficient language use, might boost lexical retrieval. In another study employing a sentence repetition task, translators outperformed bilingual controls (Ibáñez et al.,) and showed no switching costs between languages, unlike bilinguals, suggesting more efficient bilingual language control.

Cognates are frequently used as experimental items in lexical processing studies. These are words sharing the same meaning and form across languages and have thus been “identified as a valuable means to study lexical access and representation in the bilingual lexicon” (Tercedor, 2011, p. 178). Numerous studies point to cognate facilitation effect, i.e. faster processing due to cross-linguistic similarity (Kroll et al., 2002). Translation scholars have also been interested in how cognates are processed and whether cognate or non-cognate translation equivalents are used. Hansen-Schirra et al. (2017) conducted a series of studies and corpus analyses on cognate translations with translation trainees and found that whether cognate or non-cognate translation equivalents are selected depends on the language status (e.g. German accepts more cognates than Slovene), context (more non-cognate solutions in text as opposed to isolated words) and translation training (more experienced trainees use fewer cognates). The authors interpret the findings by claiming that the mental lexicon is modulated with experience and that experienced students have more attentional resources available for monitoring. Tercedor (2011) explained the frequent occurrence of cognates in translation via the priming effect, which means that due to cross-linguistic similarity, cognate equivalents are activated first and selected as translation equivalents. It seems that participants with more translation experience tend to avoid cognate translations more than controls (Lijewska & Chmiel, 2015; Tercedor, 2011; but see Lijewska & Chmiel, 2015), while there are more cognate translation equivalents in interpreting than in written translation due to greater cognitive effort and temporal constraints in the former (Oster, 2017; Shlesinger & Malkiel, 2005).

12.2.2 Syntactic processing

In general, syntactic processing in translation might be facilitated by similarity of syntactic structures (Maier et al., 2017). Similar structures have shared representations and prime equivalent translation structures. When working between languages from different language families, translators may be more frequently forced to engage in syntactic restructuring (Gernsbacher & Shlesinger, 1997).

Numerous studies have focused on word order that requires reordering in the target language and syntactic structures that necessitate restructuring in translation. For instance, Jensen et al. (2009) found that source-text items in L1 (Danish) that required a changed word order in L2 (English) generated longer gaze times, interpreted as increased processing effort. This finding was corroborated by Balling et al. (2014) in translation involving the same language pair. Additionally, they conducted two further experiments with L1 and L2 reading to confirm that longer gaze times for non-congruent experimental items (i.e. those that required a word order change) were related to parallel processing in translation rather than the language-specific difficulty of such structures. These findings were also in line with Schaeffer et al. (2016), who found that areas of interest that required syntactic source–target-language reordering increased first fixation durations (interpreted as a representation of automatic processes) and total reading time (understood as a representation of later and more conscious processing).

An interesting approach to syntactic processing was offered by Bangalore et al. (2016), who used empirical data from the CRITT-TPR database (Carl et al., 2016) to examine how syntactic variation influences cognitive effort, operationalized by reading and typing patterns. They found that syntactic structures that could be easily rendered into the target language without
any restructuring requirements were translated literally and that structures with higher syntactic entropy (i.e. with several potential equivalent structures in the target language) induced longer reading times and less smooth typing. They interpreted their findings in favour of cross-linguistic priming of shared representations, which means that if a structure is shared between source and target language, it is easier to translate. These results corroborated the findings of earlier experimental studies: by Vandepitte and Hartsuiker (2011) with constructions that required restructuring the agent and the predicate in the target language and by Ruiz et al. (2008).

In another study, Serbina et al. (2017) looked into English–German restructuring based on word-class shifts by using keylogging and eye-tracking data obtained from professional translators and domain experts. They found numerous shifts from verbs to other parts of speech, explained by the feature of German being a more nominal language than English. They also reported increased cognitive effort (operationalized as total fixation duration and fixation count) for more complex structures and changes in grammatical complexity.

Studies on syntactic processing in interpreting and sight translation are less numerous. Timarová et al. (2015) found that syntactic processing in interpreting correlated positively with experience but not with working memory scores; i.e. more experienced interpreters, regardless of their memory capacity, performed better when interpreting sentences with double subject-relative clauses. As in studies on written translation, sentences requiring restructuring in the target language triggered greater cognitive effort in interpreting, as evidenced by pupil dilation (Seeber & Kerzel, 2011) and information retention (Viezzi, 1989). Shreve et al. (2011) manipulated syntax by including either simple sentences or a complex sentence with embedded relative clauses into the text. On the basis of reading and disfluency measures, they concluded that paragraphs containing less complex sentences were less effortful to process. Interestingly, more difficult syntactic structures triggered longer translation durations but shorter reading times in sight translation (Chmiel & Lijewska, 2019), suggesting that the participants looked away from the text to avoid visual interference from source-language structures. Additionally, an experience effect was found in syntactic processing in simultaneous interpreting, with professionals performing better than trainees (Riccardi, 1996). However, in another study, trainees were found to restructure more than professionals (Setton & Motta, 2007), while Chmiel and Mazur (2013) found no difference in the processing of simple and complex sentences in sight translation performed by more and less advanced interpreting trainees.

Syntactic processing has also been examined in audiovisual translation. Gerber-Morón and Szarkowska (2018) and Gerber-Morón et al. (2018) examined reading of syntactically segmented and non-syntactically segmented subtitles, and although no differences were found in comprehension, higher cognitive load and different reading patterns were reported for non-syntactically segmented subtitles. Additionally, longer fixations (Perego et al., 2010) and more difficult processing (Rajendran et al., 2013) were reported for such subtitles in other studies. Chmiel, Lijewska, et al. (2017) examined structural paraphrasing in respeaking, i.e. live subtitling in which the translator repeats the spoken content to be transformed into subtitling text in an automatic speech recognition system. They found that the translation and interpreting experience of respeakers did not modulate paraphrasing quality or speed. Syntax was also examined in audio description: Mazur and Chmiel (2016) manipulated sentence complexity and found that simpler syntax generated higher recall, comprehension and visualization scores among blind participants.

### 12.2.3 Temporal aspects of processing

Processing in translation can also be studied by focusing on its temporal aspects. According to Timarová et al. (2011, p. 121), “[t]ime lag provides insight into the temporal characteristics of
simultaneity in interpreting, speed of translation and also into the cognitive load and cognitive processing involved in the translation/interpreting process.”

In simultaneous interpreting, the most important temporal measure is EVS, also known as décalage, defined as the interval between the interpreter’s hearing the source-text unit and its production in the target language (Lee, 2002; Pöchhacker, 2004). EVS have been found to last 2–6 s (Defrancq, 2015; Oléron & Nanpon, 1965; Timarová et al., 2011). It is modulated by the syntactic complexity of the source text (Adamowicz, 1989), sentence length (Lee, 2002), source-text speed (Lee, 2002), working with or without text (Lamberger-Felber, 2001), and previous preparation (Díaz-Galaz et al., 2015).

Pauses have also been studied as a temporal aspect of interpreting. They have been linked to problems with both comprehension and production (Goldman-Eisler, 1972; Piccaluga et al., 2005). They can also be used strategically to gain time while processing the input (Tissi, 2000). Pausing patterns can be modulated by experience (Tóth, 2013), directionality and source-text speed (Piccaluga et al., 2005). In sight translation, speech disfluencies (unfilled and filled pauses, repetitions and revisions) were also found to provide information about cognitive processes, such as visual interference, since more difficult sentences generated less fluent output (Shreve et al., 2011). Both EVS and pauses have also been examined as temporal aspects of respeaking: Chmiel, Szarkowska, et al. (2017) found that interlingual respeaking was more difficult than intralingual, as the former generated longer EVS and longer pauses, and because both EVS and pauses were longest when respeaking a text spoken with a fast delivery rate.

The equivalent of EVS in written translation is EKS, or eye–key span, the interval between reading the source-text unit and typing its translation in the target language. Timarová et al. (2011) compared professional translators and trainees and found more stable EKS patterns in the group of professionals. The authors interpreted the higher EKS values for trainees as reflecting the construction of meaning of the source text and switching to the target-language production. Dragsted (2010) also focused on temporal aspects of translation performed by translators and trainees. She noticed integrated coordination, i.e. almost simultaneous target-text production with source-text reading, in the group of professionals, and sequential coordination, i.e. processing of larger chunks by comprehending them first and producing later, in the group of students. In line with research on interpreters, professional translators had a shorter EKS (approx. 2.8 s) as compared with trainees (approx. 7.2 s). They also had a much lower number of pauses (both production related and source-text reading related), which suggests more cognitive effort on the part of translation trainees.

With the application of keylogging software, it became possible to analyse temporal aspects of typing in translation. Pauses in translation production have been interpreted as manifestations of mental organization and problem solving (Immonen, 2006) and reflections of cognitive processing (O’Brien, 2006). Immonen and Mäkisalo (2010) found that pause length correlates with phrase boundary types and functions: pauses before main and subordinate clauses are similar (unlike in monolingual text production), suggesting separate processing of both, despite the fact that the subordinate clause is not a stand-alone segment but functions within the whole sentence. Dragsted (2005) reported that the pausing/writing ratio increases with text difficulty. She suggested two different translation modes based on pausing patterns: the analytic mode with short segment size, slow production and long pauses, and the integrated processing mode with long segment size, fast production and short pauses. Her experiment showed that professionals used the integrated mode when translating an easy text and the analytic mode when translating a difficult text, while trainees used the analytic mode for both texts.

The studies on temporal aspects of translation have also popularized the concept of cognitive rhythm as proposed by Schilperoord (1996). According to Jakobsen (2003, p. 89), “human
language processing (comprehension as well as production) proceeds by chunking of the information stream, creating a cognitive rhythm” that is marked by translation units, or segments of the source text processed by the translator (be it a word, a phrase or a sentence) (Buchweitz & Alves, 2006). It might also be defined as “‘bursts’ of creativity in between pauses” (Saldanha & O’Brien, 2014) and is linked to the analysis of translation stages and other activities, such as typing, insertions, deletions, revisions and use of information sources (Saldanha & O’Brien, 2014). Buchweitz and Alves (2006) have shown, for instance, that cognitive rhythm slows down if translators operate on small translation units consisting of single words only.

Finally, on the macro-level, the process of translation has been divided into the following stages: orientation (involving reading the source text), drafting (production of the first draft of the translation) and revision (final editing and correcting of the draft) (Jakobsen, 2002). Recent studies show that depending on the translator’s personality or style, translators may tend to combine revision with drafting or turn to revision after completing the drafting stage (Carl, Dragsted, & Jakobsen, 2011; Lehka-Paul & Whyatt, 2016).

12.2.4 Memory and executive functions

Memory and executive control performed via executive functions, i.e. mental processes that regulate cognition (Nour et al., forthcoming), have sparked interest among translation scholars, especially among interpreting researchers, because translation is a complex activity that taxes cognitive processing. In fact, functional brain changes due to interpreting experience have been found in areas supporting multilingual executive control (Hervais-Adelman et al., 2015). Many scholars have set out to examine how memory and executive control functions interact with translation.

Memory studies involving simple span tasks (such as digit and letter span, in which participants recall previously presented stimuli) have shown inconclusive results. Some studies report interpreter advantage over controls (Babcock & Vallesi, 2015; Christoffels et al., 2006), while others do not (Köpke & Nespoulous, 2006; Padilla et al., 1995). Complex span tasks (such as reading span, where participants recall final words of previously presented sentences) show interpreter advantage depending on the task: interpreters outperform controls in the reading and operational span task (Babcock & Vallesi, 2015; Christoffels et al., 2006) and the speaking span (Christoffels et al., 2006) but not in the listening span (Köpke & Nespoulous, 2006) or the symmetry span task (Babcock & Vallesi, 2015). The majority of studies found no difference between professional interpreters and trainees. This pertains to both simple span tasks (Köpke & Nespoulous, 2006; Padilla et al., 1995) and complex span tasks (Liu et al., 2004; Yudes et al., 2012) except for one study by Díaz-Galaz et al. (2015), who found better reading span scores for interpreters than for trainees. Longitudinal studies focusing on how interpreter training affects memory found a strengthening effect in a simple span task in a group of sign language interpreting trainees (Macnamara & Conway, 2015) as well as in reading span (Chmiel, 2018a) and short-term verbal memory measures in a group of interpreting trainees (Babcock et al., 2017). It is interesting to note that the last study used students of written translation as a control group and found no improvement in the short-term memory score as a result of training. Higher memory scores have been associated with better performance in sign language interpreting (Macnamara & Conway, 2015) and simultaneous interpreting (Chmiel, 2018a; Timarová et al., 2015), but see Timarová et al. (2015).

Following Nour et al. (forthcoming), we classify executive functions into inhibition, shifting and updating. Inhibition is the ability to suppress a dominant and automatic response to a stimulus. Shifting means switching between multiple tasks, and updating involves monitoring and applying
incoming information when necessary (Nour et al., forthcoming). As Nour et al. (forthcoming) conclude in their systematic review, interpreters have shown advantage over controls in shifting and updating but not in inhibition (Babcock & Vallesi, 2015; Dong & Liu, 2016; Morales, Padilla, et al., 2015). Similarly, longitudinal studies that compare trainees at various stages of training show that interpreter training improves shifting and updating but not inhibition (Babcock et al., 2017; Dong & Liu, 2016; Dong et al., 2018; Macnamara & Conway, 2014).

12.2.5 Directionality

Translators and interpreters are usually required to work into their mother tongue. Such L2–L1 translation is sometimes referred to as direct translation (da Silva et al., 2017) or backward translation (Christoffels et al., 2003; García & Muñoz, this volume). Translation out of one’s mother tongue into the foreign language, i.e. L1–L2 translation, is known as L2 translation (Whyatt, 2018), forward translation (Christoffels et al., 2003; García & Muñoz, this volume), inverse translation (da Silva et al., 2017) or retour in the case of conference interpreting (Pavlović, 2007). For the sake of clarity, we will use the most self-explanatory labels in this section, i.e. L1–L2 and L2–L1 translation.

The common approach is that translators should work only into their L1 due to lower proficiency in their non-native L2. However, L1–L2 translation is frequently used around the world, especially when L1 is a language of limited diffusion (Ferreira & Schwieter, 2017). Moreover, as Whyatt (2018, p. 90) argues, L1–L2 translation, especially if L1 is a minor language and L2 is English, “has been vilified without solid empirical evidence”. Fortunately, many researchers have applied a descriptive, rather than a prescriptive, approach to understand the advantages and disadvantages of translation into both directions.

Many studies focusing on directionality in translation focused on cognitive effort operationalized by eye movements or keystrokes. The patterns of results are mixed. Ferreira et al. (2016) found that translators spent more time in L1–L2 translation; their fixation durations were also longer in L1–L2 translation, but the fixation count was higher in L2–L1 translation. Pavlović and Jensen (2009) asked trainees and translators to perform translation in both directions. Their results show that L1–L2 translation turned out to generate greater cognitive effort only as measured by pupil dilation, while task length, gaze time and fixation durations did not differ statistically. The same pattern of results was obtained for target-text production in L1–L2 translation. In a keylogging study, Jakobsen (2003) found fewer text production keystrokes in L1–L2, a task speed decrease by 16% as compared with L2–L1 translation, and no difference in the revision stage between directions. These results are not uniform, and small sample sizes might have been one of the reasons. In such studies, it is not uncommon to conduct a study on four or eight participants in a group, which might compromise the power of these experiments.

Additionally, many such studies focus on reading measures globally for L1–L2 and L2–L1 translation, while more focus should be put on a separate analysis of source-text and target-text processing as a function of directionality. A good example is a study by Whyatt (2018), who compared translations performed by professional translators into L1 and L2. She measured fixation duration when reading the source text in the orientation phase, typing speed and pauses during target-text production, and the percentage of total task time devoted to revision, and found only slight differences as a result of translation directionality. In another study, da Silva et al. (2017) examined translators with one year of experience performing translation both from and into L2. They found that directionality influenced fixation count on the source text and target text and the total reading time of the target text: they reported more effort when reading target text in L1–L2 translation and more numerous fixations on L2 text when it was a source text in
L2–L1 translation. These results show an L1 processing advantage, in line with many studies on directionality in interpreting reviewed below.

The majority of directionality studies on interpreting show L2–L1 advantage, manifested in greater efficiency and more automaticity in L1 production (Gran & Fabbro, 1988), greater coherence and production ease (Donovan, 2005), greater fluency (Mead, 2005) and faster word translation (Chmiel, 2016). Opposing results were found in interpreting linguistically complex texts (Tommola & Helevä, 1998), as well as in anticipation and quality (Kurz & Färber, 2003). Chmiel (2018b) found that for both professional interpreters and trainees, words in L1 primed (i.e. accelerated recognition of) words in L2, but not vice versa, suggesting language asymmetry and L1 advantage.

12.2.6 Reading patterns

Translation scholars, especially those involved in TPR, have embraced eye-tracking as a method that can shed more light on the translation process. Obviously, the link between eye movements and cognitive processing is not as direct as originally posited by Just and Carpenter (1980) in their eye-mind hypothesis. Although many eye-tracking studies of translation interpret prolonged or more numerous fixations as an index of increased cognitive effort, one has to bear in mind a potential temporal misalignment—the eyes might fixate on one word, but the mind might be processing the neighbouring one (Jakobsen, 2017). Although reading research has developed since the 1970s (Rayner, 1998) and has established both early and late reading measures as indices of lexical and semantic processing and integration, these measures are of limited use to translation scholars because reading for translation differs so much from regular reading. One of the most obvious reasons is that the translator alternatively or concurrently reads and processes two texts.

Numerous studies have used eye trackers to determine unique reading patterns in translation. One of the now classic studies was by Jakobsen and Jensen (2008), who found that reading patterns differ depending on the purpose of reading. They compared reading while typing the target text, sight translation, reading for comprehension and reading for orientation before translation. Not surprisingly, reading while producing translation generated more and longer fixations than other tasks, while reading for comprehension generated fewer fixations than the remaining and cognitively more demanding tasks. These results were not corroborated by Alves et al. (2011), who found the longest fixations in sight translation. These conflicting results might be explained by different participant profiles in the Danish and Brazilian experimental groups, their different levels of experience with sight translation, and distinct task construals used in the studies.

A more recent study by Schaeffer et al. (2017) is an example of a well-controlled experiment, in which professional translators read single sentences either for comprehension or for translation. The authors manipulated the number of words constructing the translation equivalent (the source-language word could be translated by using either one target-language word or a phrase). The stimuli were matched for frequency, length and predictability (variables known to affect reading times). The study showed task effects in all reading measures, suggesting that the reading purpose changes reading patterns due to co-activation of both linguistic systems when reading for translation. It also offered further evidence for the recursive model of translation (Schaeffer & Carl, 2013) and parallel operation of vertical and horizontal translation processes.

Hvelplund (2017) conducted an even more fine-grained analysis of various reading types involved in translation and analysed fixation durations and pupil dilation separately in source-text reading, source-text reading while typing, reading of the existing target text, and reading of the emerging target text (while typing). He found longer fixation durations and larger pupil sizes.
for the target text as compared with the source text and in the emerging target text as compared with the existing target text. The latter finding was explained as reflecting such processes as verification of spelling and punctuation in the produced text and, more importantly, reformulation, i.e. construction of a pre-verbal version of the source text in the target language, comparison of meaning, and subsequent lexical and syntactic encoding of the target text for typing purposes.

In other studies, reading patterns in translation have been found to be modulated by syntactic complexity (Balling et al., 2014; Bangalore et al., 2016; Jensen et al., 2009), the number of potential translation equivalents of a fixated source-language word (Schaeffer et al., 2016), directionality (da Silva et al., 2017; Ferreira et al., 2016; Pavlović & Jensen, 2009; Whyatt, 2018), time pressure (Sharmin et al., 2008), source-text difficulty (Hvelplund, 2011), translation experience (Carl et al., 2011; Dragsted, 2010) and translation style (Carl et al., 2011).

New applications of eye-tracking measures are being proposed as the field is developing. For instance, Hvelplund (2016) used eye-tracking measures combined with keylogging measures to operationalize cognitive efficiency in translation. Chmiel and Lijewska (2019) suggested a novel measure for analysing sight translation: percentage of dwell time, understood as the percentage of total sight translation time spent viewing the sentence. A low value of the percentage of dwell time means more looking away from the text while sight translating to avoid source-text interference. Finally, Kruger and Steyn (2014) introduced a Reading Index for Dynamic Texts, used to analyse subtitle reading and to determine to what degree a subtitle was read in the context of a dynamic audiovisual material.

12.3 Recent developments and future directions

Certain models of translation and interpreting can be considered psycholinguistically motivated, and these are briefly reviewed below. Authors such as de Groot and Christoffels (2006), Macizo and Bajo (2006), and Ruiz et al. (2008) distinguish between vertical and horizontal translation strategies. In vertical or conceptually mediated translation, the source-language message is first decoded, and its conceptual representation is activated through phonological, morphological and semantic analysis; then its lexical representation in the target language is activated for production. In horizontal or structurally mediated translation, source-language utterances are directly transcoded into their target-language equivalents through memory associations (de Groot & Christoffels, 2006). Translators and interpreters might use either strategy depending on context.

Additionally, words in two languages might have semantic fields overlapping to a greater or smaller extent. In a study involving non-translating bilinguals, words with one-to-one mappings, i.e. words that have a single translation equivalent, have been found to be translated faster, while words with many translation equivalents are translated more slowly because activation reaches more candidates and inhibition must take place to choose the right equivalent (Tokowicz & Kroll, 2007). This modulation of word translation by the number of its translation equivalents has been studied in written translation and is known as the word translation entropy effect (Schaeffer et al., 2016).

The division between vertical and horizontal translation has been used as a framework for defining other models in translation. Tirkkonen-Condit (2005) proposed the monitor model of translation, according to which literal or horizontal translation is the default used by professionals and trainees alike. Production is constantly monitored, and a non-literal solution is proposed when problems occur. This model was empirically tested by Carl and Dragsted (2017), who compared eye-tracking and keylogging data from copying and translating and found more interventions from the monitor mechanism in translation, as manifested by less linear typing and reading patterns.
The monitor model and the horizontal/vertical translation dichotomy have served as a basis for another interesting model that interfaces with psycholinguistics, i.e. the recursive model of translation (Schaeffer & Carl, 2013). According to this model, most of the translation is done horizontally thanks to shared bilingual representations (both lexical and syntactic). Such horizontal priming (i.e. activation of parallel target-text structures due to exposure to source-text structures) is the default translation mode. To test the model empirically, Schaeffer and Carl (2013, p. 184) compared verbatim recall (as a measure of priming) after comprehension and translation and concluded that “for the translator, every sentence acts as a prime—when cross-linguistic similarity allows”. In the recursive model, translation proceeds mainly horizontally (through early activation of shared representations), and vertical processes serve as the monitor. When the horizontally produced target text is not acceptable, vertical processes adapt the text to the target-language norms. These processes also control equivalents, so both languages have to be active during production. “Vertical processes access the output from the automatic default procedure recursively in both the source and the target language and monitor consistency as the context during translation production increases” (Schaeffer & Carl, 2013, p. 186). The recursive model thus integrates the monitor model with the horizontal/vertical translation strategies and is backed by experimental data and psycholinguistic findings from priming studies.

Another interesting attempt to combine translation process models with psycholinguistics is Halverson’s gravitational pull hypothesis (Halverson, 2004), which uses the premises of the distributed feature model (DMF) of the bilingual mental lexicon to explain translation universals. According to DMF (de Groot, 1992), word meanings or senses are represented as sets of features. The overlap in the meaning of translation equivalents is larger if more features are shared. Following psycholinguistic research, Halverson assumes one knowledge store for both languages and various patterns of activation between concepts and words. For instance, more concrete and more frequent words are more easily activated and translated faster, as they exert “gravitational pull”. As a result, highly salient features (not only words but also structures) will be more easily activated and over-represented in the translated text. Interestingly, Gile (2009) uses a similar metaphor of gravitational forces in his gravitational model of linguistic availability, in which more frequently used language constituents become more available. Although this model does not interface with psycholinguistic models in any way, it uses a similar concept of a dynamic structure of language that undergoes change due to linguistic experience.

Gile is the author of probably the most influential models of interpreting, the so-called effort models (Gile, 2009). The models posit that the interpreter distributes limited cognitive resources among various efforts, such as listening and analysis, production, memory and coordination. Even the most experienced interpreters make errors due to insufficient resources as they work near the saturation level, called by Gile the tightrope hypothesis (Gile, 2009). According to de Groot and Christoffels (2007), clear similarities between Gile’s approach to interpreting as a divided-attention task and psycholinguistic theories can be found. However, the models have been criticized by Seeber (2011) for being based on an obsolete single-resource theory of attention (Kahneman, 1973) and for assuming possible shifts of attention between efforts. Seeber proposed his own cognitive load model based on the multiple resource model (Wickens, 1984), according to which tasks may interfere with each other depending on whether they are supported by similar mechanisms. Comprehension and production in interpreting are divided into demand vectors, which have various conflict coefficients that reflect interference. The model was tested empirically based on pupil dilation data from a task involving simultaneous interpreting of symmetrical and asymmetrical structures. Cognitive load increased in asymmetrical structures, thus lending support to local cognitive load variation posited by the model. However, the model
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has not been developed further so far to account for other types of interpreting, and no further studies have been conducted to test its assumptions.

The intersection of translation, cognition and psycholinguistics brings an important benefit in the form of research designs and methodology. Group comparisons are especially interesting as being directly related to the interpreter advantage hypothesis put forward by García (2014, p. 219), according to which “task-specific cognitive skills developed by professional interpreters […] generalize to more efficient linguistic and executive abilities in non-interpreting tasks”. In fact, many studies have compared professional interpreters, interpreting trainees and non-interpreting bilinguals in a variety of both interpreting and interpreting-related tasks (Babcock & Vallesi, 2015; Bajo et al., 2000; Chmiel, 2018a; Dong & Liu, 2016). The findings of these studies may be cautiously interpreted as a certain superiority of interpreters over trainees and trainees over controls in such aspects as information prioritizing, cognitive capacity management, fluent delivery, semantic processing, syntactic restructuring, verb anticipation and various aspects of working memory and executive functions, such as shifting and updating. It is possible that interpreting experience and training may trigger interpreter advantage. However, further studies and replications are needed to make a more definitive statement.

Group comparisons have also been used in study designs involving written translation. Translation tasks performed by professional translators have been found to last for a shorter time and trigger less cognitive effort than in the case of trainees, as measured with eye-tracking (Dragsted, 2010; Hvelplund, 2016; Pavlović & Jensen, 2009) and keylogging data (Jakobsen, 2003). Professional translators further outperform trainees in flexibility and adaptability (Hvelplund, 2016), shorter or more stable EKS and a lower number of pauses (Dragsted, 2010; Timarová et al., 2011), but not in the number of revisions (Jakobsen, 2003).

The range of methods used by translation scholars is growing. Experiments include translation and interpreting tasks with high ecological validity (e.g. written translation, sight translation, simultaneous interpreting with and without text, consecutive interpreting and paraphrasing) and translation-related tasks (such as single word translation or sentence translation), reading for translation, and more controlled experimental tasks such as lexical decision or picture naming. Research methods are mostly behavioural, including eye tracking and keylogging, priming, screen capturing, and audio and video recording. The application of neurolinguistic methods (such as electroencephalography (EEG) and functional magnetic resonance imaging (fMRI)) is on the rise. The dependent variables, i.e. what is measured in empirical studies due to experimental manipulation, usually include reaction times, accuracy and quality of output, reading measures (such as, for instance, first fixation duration and total reading time), keylogging measures (such as keystroke count and revisions) and temporal measures (EVS, EKS and pauses). In line with Alves’ call for data triangulation in Translation Studies (Alves, 2003), more and more studies are using a mixed-methods approach (for instance, they combine eye tracking and keylogging or reaction times and event-related potentials in EEG studies) to arrive at results well grounded in data from various sources.

As Translation Studies further interacts with psycholinguistics and taps into the richness of psycholinguistic research methods with rigid control of variables and experimental conditions, it should also embrace most recent developments in statistics. The use of linear mixed models (Baayen et al., 2008) is becoming more and more predominant in psycholinguistics and has found its first applications in Translation Studies as well. Linear mixed models are gaining popularity over the more traditional analysis of variance (ANOVA) because they handle unbalanced designs better (e.g. where the number of participants or items is not equal in each experimental condition) and take into consideration random factors of both participants and items (e.g. the fact that some participants may be slower than others and that some stimuli might be easier than
Additionally, it should now be standard to report effect size for statistically significant tests (i.e., not only whether the observed difference is significant but also how big it is) and to take care of experimental power. This means having sufficient numbers of participants and items in the experimental studies, so that the expected effect is not missed due to an underpowered experiment, or so that the significant effect is not due to type M error (an exaggerated effect found by chance) (Vasishth et al., 2018). It is important to report statistical analyses in full in order to ensure replicability of studies. If the same effect is reported repeatedly by many scholars, it becomes a much stronger foundation for building our knowledge about psycholinguistic aspects of translation than a single study.

Another interesting development in psycholinguistics that may have direct influence on translation is the latest Multilink model of the bilingual mental lexicon (Dijkstra et al., 2018), which posits language non-selective lexical access and a multiplicity of cross-level activations. This model, as the authors themselves admit, is especially suited to explain word translation mechanisms but has not been tested on translators or interpreters so far. In general, future studies should focus on more integration between translation and psycholinguistics, as scholars attempt to explain their experimental results with psycholinguistic models and integrate existing translation models with the current state of knowledge based on psycholinguistic studies. The ensuing synergy will help translation scholars discover more about the nature of processing in translation and will help psycholinguists find out more about linguistic processing under difficult conditions.

The overview of the psycholinguistically oriented studies in translation included in the present chapter shows the great potential of studies that aim at gaining insights into the cognition of translation, be it lexical or syntactic processing, memory and executive functions, reading or temporal patterns of processing. With the application of rigid methodologies and study designs, statistical modelling, and the integration of cognitive processing models in psycholinguistics and translation, we can hope to discover more about the cognitive nature of the fascinating task of translation in the future.

**Further reading**


An overview of studies on working memory in interpreting and a discussion of current models of memory and interpreting.


A systematic overview of psycholinguistic studies in audiovisual translation.


One of the latest studies focusing on interpreter advantage and on the effect of extreme processing demands of simultaneous interpreting on lexical processing.

**References**


Chmiel


