16
TRANSLATION PROCESS RESEARCH
An overview

Sanjun Sun and Jun Wen

16.1 Introduction

In his influential paper 'The Name and Nature of Translation Studies,' Holmes (1988) proposes two main objectives for this discipline: (1) to describe the phenomena of translating and translation(s), and (2) to establish general principles that can explain and predict these phenomena (Holmes 1988: 71). Based on these objectives, he distinguishes between theoretical translation studies and descriptive translation studies (DTS), the latter of which examines the translation product, its function and the translation process. Process-oriented DTS is concerned with the process or act of translation itself. Holmes suggests that this area of study may be called translation psychology, which has been adopted by many Chinese researchers (e.g., Liu 2007). Yet, in the international literature, it has usually been called translation process research (henceforth TPR).

The term 'translation process' has many folds of meanings (see Neubert and Shreve 1992: 53), which may be grouped into internal process and external process. The internal process refers to the unobservable cognitive processes activated during translating; the external process is the course of action applied by the translator to actual texts. When translation researchers discuss memory and representation in translation, for instance, they refer to the internal process; when they investigate translators' observable behaviour (e.g., revising), they mean the external process. Of course, the line between the two often is fine.

The cognitive process of translation is complex. In simple terms, it involves three basic steps: (1) source text comprehension, (2) transfer of meaning from source text to target text, and (3) target text production. Although it is possible to view translation as a linear process when the translator encounters no difficulties, research has indicated that the process of translation 'has an interactive and non-linear nature, encompasses controlled and uncontrolled processes, and requires processes of problem-solving, decision-making and the use of strategies' (Hurtado Albir and Alves 2009: 63).

The analysis of the translation process, accordingly, involves consideration of many factors, including translator factors (i.e., various translation competences), text factors (i.e., elements of the text that impact cognitive processing, such as readability), task factors (e.g., translation directionality, constraints of the task such as time pressure) and different forms of translation (e.g., written translation, interpreting, sight translation, post-editing).

Given this complexity and the interdisciplinary nature of the discipline, translation process research has been drawing on many disciplines and sub-disciplines, including linguistics, psychology, reading and writing research, and others. These feeder disciplines can, in a way, be grouped under cognitive science, which can provide a referential framework for this heterogeneous area. Norman (1980) lists 12 issues for cognitive science: belief systems, consciousness, development, emotion, interaction, language, perception, learning, memory, performance, skill and thought. The translation-related parts of these issues are all concerns of TPR.

16.2 Historical perspectives

The importance of TPR was recognised early in the twentieth century. For example, Lin Yutang (1895–1976), a well-known Chinese writer and translator, mentioned in 1933 that issues in translation could be boiled down to the relationship between the translator's mind and the text (Lin 1984: 419). Empirical research into the (written) translation process emerged in the mid-1980s (e.g., Krings 1986), while experimental studies of interpreting, which were mostly conducted by psychologists, first appeared in the 1960s (see Gerver 1976).

Over the decades, TPR has been gaining considerable momentum. By 2000, according to an annotated bibliography (Jääskeläinen 2002), there were more than 100 process-oriented studies that mainly drew on think-aloud protocols. From 2000 to 2015, there were at least 20 edited volumes in English devoted to TPR, including at least three volumes since 2015 (e.g., Carl et al. 2016). Several translation journals have published special issues on TPR, such as *Meta* 41/1 (1996), 50/2 (2005); *Across Languages and Cultures* 3/1 (2002), 10/2 (2009), *Target* 25/1 (2013); *Translation and Interpreting Studies* 8/2(2013), 9/1 (2014); and *MonTI* (2014). In China, TPR began with reviews of published literature in English on process-oriented translation studies (e.g., Jiang 1998). In recent years, there have been at least ten Chinese monographs published on cognitive inquiries into translation and interpreting (e.g., Zhang 2011; Zheng 2012), and dozens of empirical studies (mostly MA and doctoral theses).

There are three basic drivers for the evolution of process-oriented translation studies, aside from its own steady growth: (1) introduction of research methods and techniques from other disciplines; (2) introduction of theories, perspectives and concepts from other disciplines; and (3) the dynamic interaction between translation theory and emerging translation practice (e.g., adoption of translation technology). The following paragraphs discuss the history of translation process research from the perspectives of the first two drivers.

16.2.1 Methodological developments

Before 2000, the primary research method adopted by translation process researchers was think-aloud protocols (TAP), by which participants are requested to speak out their thoughts while translating a text. Mainly based on Ericsson and Simon (1993), TAP is a method from cognitive psychology and was first applied to TPR by Krings (1986) and others.

In the mid-1990s, keystroke logging was introduced into TPR. It allows researchers to trace keyboard actions, cursor movements and pauses. As a method for cognitive process research, keystroke logging originated in writing research. One of the earliest attempts to use keystroke logging in TPR was that of Englund Dimitrova (2005), who collected data using ScriptLog in 1993 and 1994. Translog (Jakobsen and Schou 1999) as a tool specifically developed for TPR has been used in dozens of studies.

Eye-tracking, a method that has been widely used in psychology and computer science since the 1960s, was first used in simultaneous interpreting research by Hyönä, Tommola and Alaja

(1995), and in (written) translation research by O'Brien (2006). To date, there have been at least two edited volumes on eye-tracking studies of translation process (Göpferich et al. 2008; Grucza et al. 2013).

According to Carl, Bangalore, and Schaeffer (2016), in the past five years or so, there have been two technical developments that give further momentum to TPR: (1) the extension of Translog for languages with different scripts (e.g., Chinese) and a tighter integration with eye-trackers, and (2) the creation of a large database of TPR data.

In China, the major method adopted in TPR has been TAP for its relative ease of use. Translog did not support English–Chinese translation until a few years ago, and eye-tracking equipment has not been easily accessible.

16.2.2 Approaches in TPR from the perspective of cognitive science

According to Halverson (2009: 215), cognitive perspectives on translation and interpreting basically follow the developments of cognitive science (see also Alves 2015; Muñoz Martín 2010; Risku 2013). Cognitive science is the interdisciplinary study of mind and intelligence. It emerged in the late 1950s and draws on a host of disciplines such as philosophy, psychology, neuroscience, artificial intelligence, linguistics and anthropology. The central hypothesis of cognitive science is that '[t]hinking can best be understood in terms of representational structures in the mind and computational procedures that operate on those structures' (Thagard 2005: 10). There have been three approaches to cognitive science: classical, connectionist and embodied. They all view cognition as a form of information processing (alternatively called computation) despite their disagreements on the nature of the representations and other technical details (Dawson 2013: 418).

The classical approach was the first in cognitive science, and arguably still dominates the field. It takes the digital computer as the most promising model for understanding the mind, and interprets information processing as rule-governed mechanical manipulation of symbols (Dawson 2013). Connectionist cognitive science arose in the late 1980s. Inspired by the physiology of the brain, connectionist theorists proposed the artificial neural network, by which they see 'reasoning as the behaviour that emerges from the direct interactions found in large networks of simple processing components', analogous to neurons (Dinsmore 2014: vii). The connectionist approach, also called the parallel distributed processing approach, argues that many cognitive operations can proceed simultaneously (or in parallel) rather than sequentially (or linearly). Embodied cognitive science claims that the brain alone should not be the sole focus of the study of cognition. A radical thesis of this approach is the extended mind, which argues that the mind extends outside the brain, into the body and the world, and emphasises how the body shapes the way we think (Dawson 2013).

Translation process research, especially in its early stage, tends to describe translation as a problem-solving and decision-making process, whose characteristics have been regarded as a central concern in TPR (Alves and Gonçalves 2003). Implicitly, those translation process researchers have adopted the classical cognitive science approach to translation, and viewed translation as a mental operation on internal processing units (Alves 2015; Risku 2013). Many models of the translation process (e.g., Bell 1991) follow the classical approach.

Over the years, process researchers have found that the process of translation has a non-linear nature and allows for recursive processes in comprehension and text production. Building on connectionist principles, Alves and Gonçalves (2007) propose a model of translator's competence with many operations being carried out in parallel. In his Chinese monograph on the psychology of translation, Liu (2007) puts forward a neural-network model for the translation

process, made up of three layers: ST input layer, bilingual processing/transfer layer and TT processing/output layer.

In line with embodied cognitive science, translation researchers argue that the translation process cannot be dissociated from the social-cultural environment it is embedded in (Alves 2015: 23). It has been proposed to expand the concept of the translation process to include aspects of translation workflow starting from the moment the translator is contacted by the client and ending when the translator is paid (e.g., Muñoz Martín 2010). This means that researchers need to investigate situational events and take into account people involved in the translation process (e.g., clients) and the computer-supported cooperative environment (e.g., translation tools). For process-oriented translation studies based upon 4EA (i.e., embodied, embedded, enactive, extended, affective) cognitive frameworks, Muñoz Martín (2010) coined the term *cognitive translatology*, which emphasises the interaction between translators and their environment. This term has started to gain currency.

Each of the three cognitive approaches has its own accomplishments and problems, and none can provide a sufficient explanation of cognition. As an integrative or unified approach is not easy (if not impossible), there have been voices (e.g., Dawson 2013) for recognising that each approach is investigating an incomplete aspect of cognition, and researchers need to combine these different points of view.

16.3 Critical issues and topics

From the perspective of research design, issues and topics in TPR can be roughly grouped into causal factors (which can be manipulated) and effect factors (which can be observed, measured or investigated) by drawing on a model by Meshkati (1988) in psychology. Causal factors include forms of translation, translator factors, text factors and task factors. Effect factors are translation-related cognitive behaviours and their modelling, including problem-solving, decision-making, automaticity, consciousness, memory, attention, reasoning and thinking, metacognition, workload, performance, learning, language comprehension, language production, cognitive development, creativity, choice under uncertainty, human–computer interaction, emotion and others. These factors in the effect group are, of course, not equally important for TPR; some are more central to translation studies than others. This section describes the topics in early TPR and then focuses on recent critical issues and topics in TPR.

16.3.1 Early topics concerning translation as problem-solving

Early TAP-based translation studies viewed translation as primarily a problem-solving activity, and were concerned with translation strategies, automaticity, translation units and affective factors (see Bernardini 2001), which are legacy concepts in translation studies or linguistics (Shreve and Angelone 2010) and are still being discussed.

Translation strategies

Strategies of translation refer to potentially conscious and controllable problem-solving procedures that translators employ. They have been a major topic in TPR because of the pedagogic concerns of researchers. There have been different classifications of translation strategies in TPR (see Sun 2013). Lörscher (1996) compared the strategies adopted by professional and non-professional translators, and noticed that they differed in the distribution and frequency of the strategies employed but did not differ qualitatively, i.e., their mental processes did not reveal

significant differences. Luo and Zhao (2015), in a preliminary TAP-based study, investigated the factors influencing the choice of translation strategies, which were found to be types of source text, purpose of translation, ideology, translator's way of thinking and their aesthetic orientation. Strategies are often considered to be part of procedural knowledge (i.e., knowing how), as opposed to declarative knowledge (i.e., knowing that). As a result of extensive practice, some procedural knowledge becomes automatised and is exercised without any need for conscious monitoring.

Automaticity

Automaticity refers to being able to perform a task quickly with little thought or conscious effort. It is important because automating lower-level cognitive skills saves our resources for higher-level cognitive tasks such as monitoring the outcome of our performance. Automaticity can be acquired, and yet some processes may just never become automatic (Palmeri 2003). This concept is closely tied with concepts of attention, consciousness, memory and cognitive effort. In TPR, researchers have tried to find out whether the performance of professional translators is more automatic than that of non-professionals, and one finding was that semi-professionals showed more extensive processing than both professionals and novices (see Jääskeläinen 1997).

Translation units

Consistent with Bernardini's (2001) suggestion that translation units should be defined in hierarchical rather than sequential terms, Alves and Vale (2009) distinguish between a micro translation unit (TU) and a macro TU. A micro TU refers to 'the flow of continuous TT production – which may incorporate the continuous reading of ST and TT segments – separated by pauses' that can be operationally defined as at least five (or, e.g., three) seconds long in the translation process, while a macro TU is 'a collection of micro TUs that comprises all the interim text productions that follow the translator's focus on the same ST segment from the first tentative rendering to the final output that appears in the TT' (Alves and Vale 2009: 257). For example, a translator is translating '我们屋后有半亩隙地' into English. She reads this ST segment, types 'Behind our house there was', shifts the gaze to 半亩 in the ST segment, and pauses for five seconds. The moves before this pause constitute a micro TU. After a sequence of moves, she finally renders the ST segment into 'There was a small patch of vacant land behind our house'. The collection of micro TUs related to this ST segment is a macro TU.

Early process researchers were interested in whether professionals work with larger chunks of text than non-professionals. The cause of such an interest in translation units has been attributed by some researchers (e.g., Barkhudarov 1993) to translation pedagogy in the belief that students can be taught how to segment texts in order to produce good translations. This, however, might not be the case, because during translation the unit of translation changes according to the translator's cognitive and processing needs (Alves and Gonçalves 2003). In this sense, translation unit is closely related to, or can be replaced by, the concept of chunking in psychology, which can be seen as a deliberate, conscious process (i.e., goal-oriented chunking) or a more automatic and continuous process (i.e., perceptual chunking) (Gobet and Lane 2012). Chunk-based theories have stimulated active research in several aspects of learning and expertise. On the other hand, the unit of translation in TPR can be taken as a unit of analysis for investigating such phenomena as focus of attention and cognitive effort (see Saldanha and O'Brien 2013).

16.3.2 Modelling translation process

Models are believed to play indispensable cognitive roles in science. In TPR, model building had been a major focus before the year 2000. This section presents a few major translation process models.

Nida's model of the translation process is one of the best known. Taking translation as a form of communication, it consists of three stages: (1) analysis of the surface structure of the source text, (2) transfer of the analysed material in the translator's mind from language A to language B, and (3) restructuring of the transferred material to make the final message acceptable in the receptor language (Nida and Taber 1969). Similar to Nida's model in form, the interpretive model, championed mainly by Seleskovitch and Lederer from the 1960s onwards, identifies three overlapping stages of the interpreting process: comprehension, deverbalisation and reformulation (see Lederer 2003). For written translation, there is a fourth stage called verification. The interpretive model believes that translators translate sense, not words.

Bell (1991) proposes a translation process model in which the processing proceeds interactively in both a sense-oriented top-down and a sign-oriented bottom-up manner, and allows for constant revision of earlier decisions. His model presupposes that all processing is rational and conscious, and ignores unconscious automatic processing. It contrasts with the psycholinguistic model of translation processes proposed by Kiraly (1995), which consists of the following principal components: (1) information sources, (2) the intuitive workspace, which is relatively uncontrolled and subconscious, and (3) the controlled processing centre.

Gile's (1995/2009) Effort Models attempt to explain the considerable difficulties inherent primarily in simultaneous interpreting, which can be modelled as a process consisting of three core components or Efforts: a Listening and Analysis Effort, a Short-Term Memory Effort, a Speech Production Effort, plus a Coordination Effort. When the total processing capacity requirements exceed the available processing capacity, or when the processing capacity available for a given Effort is not sufficient for the task, problems occur and the interpreting performance begins to deteriorate.

Models in TPR differ with respect to scope, form and purpose. In terms of scope, there are full process models and partial process models (that is, representing only certain features of the translation process). Based on senses of 'translation problem', Chesterman (2013) distinguishes three types of models: (1) models of virtual processes, which show the potential path from a translation problem to a potential solution and are pedagogically useful (e.g., Nida's model); (2) models of reverse-engineered processes, which aim to reconstruct the possible route taken to a given factual solution (e.g., Gile's Effort Models); and (3) models of actual processes of translation (e.g., Schaeffer and Carl 2013). Most of the existing models in TPR are descriptive and few incorporate causality, hence their lack of predictive power. As said by Shreve and Angelone (2010: 4), 'widespread and commonly-accepted process models of translation have yet to emerge in the discipline'.

16.3.3 Translation competence and expertise

Translation competence (TC) is a topic central to translator training and of immense importance in TPR. Defining it is tricky, however. According to PACTE (2005: 610), translation competence refers to the underlying knowledge system needed to translate. Other terms used for translation competence include translation skills, translation ability, translation proficiency and translation expertise. Yet, they are not the same. Dreyfus and Dreyfus (1986) distinguish five stages of skill acquisition, from novice stage to advanced beginner, competence, proficiency

and then to expertise stage; conscious decision-making enters the picture at the competence stage, for in order to make decisions, learners need to know what choices are available and why some choices may be better than others. Along this line, Pym (2003: 489) identifies two skills needed for TC, namely (1) the ability to generate a series of more than one viable target text for a pertinent ST, and (2) the ability to select only one viable TT from this series, quickly and with justified confidence.

There are two major issues related to translation competence (or expertise): its structure and acquisition (and maintenance). The structure of TC concerns its components (or sub-competences). In this regard, there have been various proposals and models (see Hurtado Albir and Alves 2009). PACTE (2005) through empirical studies lists five sub-competences (including bilingual, extra-linguistic, instrumental, knowledge-about-translation and strategic sub-competences) and psycho-physiological components (such as memory, attention). These sub-competences are, of course, not equally important. Translators of different competency levels engaged in the same task may not be solving the same problems. For instance, if there are allusions in the source text, some translators may recognise them while others may not.

The acquisition of TC refers to the developmental progression by which bilinguals acquire professional translation competence. It is now accepted that individual translation subcompetencies may not develop at the same rate, nor will they develop in a linear fashion (Göpferich 2013). In order to reach the stage of expertise featuring consistently superior performance for representative tasks in a domain, translators need deliberate practice, i.e., engaging in tasks with goals that exceed the current level of performance (Shreve 2002).

16.3.4 Translation difficulty and workload

Translation difficulty refers to the extent to which cognitive resources are consumed by a translation task for a translator to meet objective and subjective performance criteria. Terms similar to or synonymous with difficulty include mental load, mental workload, cognitive workload, cognitive load, cognitive effort, mental effort and so forth. Mental load (or cognitive effort), according to Muñoz Martín (2012: 172), is 'a construct of paramount importance' for TPR, and may help us unravel the complex relationships between consciousness, problem-solving, automation and expertise; it may also establish a bridge between translation and interpreting research.

On the topic of translation difficulty, two lines of research can be identified in the literature: (1) difficulties in human translation; (2) difficulties in machine translation and post-editing. In the first line of research, two essential questions are what makes a text difficult to translate and how to measure and predict the difficulty degree of a translation task (Sun and Shreve 2014). Sources of translation difficulty can be divided into two groups: task (i.e., translation) factors and translator factors. Translation factors include readability (or reading comprehension) problems and translation-specific (or reverbalisation) problems, while translator factors concern translation competence, which is more permanent, and affection (such as confidence, motivation and anxiety), which is more susceptible to change (Robinson 2001: 32). Both groups of factors influence a translator's perception of task difficulty.

16.4 Empirical findings

As noted above, over the past three decades, researchers have investigated various aspects of the process of translation and interpreting, and made substantial findings. For example, according to Hurtado Albir and Alves (2009: 62–3), the main characteristics of the translation

process include, among others, (1) the existence of basic stages related to comprehension and reverbalisation, (2) the existence of automatic and non-automatic, controlled and uncontrolled processes, (3) the role of problem-solving, decision-making and the use of translation strategies in the process, and (4) the existence of characteristics specific to certain form of translation.

This section briefly introduces findings with respect to the behavioural process of translation, the literal translation hypothesis, translation competence and expertise, and translation difficulty.

16.4.1 The behavioural process of translation

On the basis of their eye-tracking and keystroke data, Carl, Schaeffer and Bangalore (2016) have identified seven activity units (i.e., types of translator activities) in the translation process. The three basic activity units are (1) source text reading, (2) target text reading and (3) translation typing. Since source or target text reading and typing can occur in parallel, the concurrent activity units include: (4) translation typing while reading the source text, (5) translation typing while reading the target text and (6) translation typing while reading the source and the target text. The seventh type is pause (i.e., no recorded activity). The recurrent translation processing micro-cycle involves these activity units, and consists of six steps (Jakobsen 2011: 48):

1 moving the gaze to read the next chunk of new source text (and constructing a translation of it)
2 shifting the gaze to the target text to locate the input area and read the current target-text anchor word(s)
3 typing the translation of the source-text chunk
4 monitoring the typing process and the screen outcome
5 shifting the gaze to the source text to locate the relevant reading area
6 reading the current source-text anchor word(s).

Three phases can be identified from the six steps: initial orientation (reading), translation drafting and final revision. Revisions can happen during the drafting or during the revision phase. The most demanding complication of the translation process, as indicated by time and gaze data, may not be the actual drafting of the TT, but the constant monitoring and revision of the TT output (Dragsted et al. 2010).

16.4.2 The literal translation hypothesis

In translation studies, there are several interesting hypotheses related to the search for translation universals; for example, the explicitation hypothesis and the simplification hypothesis. Although they have implications on underlying cognitive processes, these hypotheses mainly concern general textual features of translations as products. One hypothesis that makes explicit claims about the translation process is the literal translation hypothesis.

A translation is literal if: (1) word order is identical in the ST and TT; (2) ST and TT items correspond one-to-one (Bangalore et al. 2016). An oft-cited discussion about the literal translation hypothesis is as follows:

> The translator begins his search for translation equivalence from formal correspondence, and it is only when the identical-meaning formal correspondent is either not available or not able to ensure equivalence that he resorts to formal correspondents

> with not-quite-identical meanings or to structural and semantic shifts which destroy formal correspondence altogether.
>
> *(Ivir 1981: 58)*

Over the years, translation process researchers seem to have found some experimental evidence in favour of this hypothesis. Englund Dimitrova (2005), for example, observed that translators may use literal translations as provisional solutions in order to minimise cognitive effort, and 'there was a tendency for syntactic revisions to result in structures that were more distant from the structure in the ST than the first version chosen' (Dimitrova 2005: 121). Several recent empirical studies (e.g., Bangalore et al. 2016) lend further support to this hypothesis.

The literal translation hypothesis is important in TPR. It has theoretical implications about the cognitive relation between form and meaning, and can be used to describe individual translator styles (Chesterman 2011). It is closely related to the issue of translation difficulty and workload. When translating, if a literal translation is an acceptable solution, translators do not have to exert much cognitive effort; if translators have to select from multiple translation alternatives and do syntactic reordering and proceed to less literal ones, the translation would involve more cognitive effort.

16.4.3 Findings on translation competence and expertise

Expertise theories have been formally introduced into translation studies by Shreve (2002, 2006), who appeals for 'leverage[ing] the expertise studies research to generate hypotheses or research questions for translation scholars to address' (2002: 168). To date, researchers in expertise studies have made many discoveries, summarised by Chi (2006) as follows. Most of the characteristics apply to translation expertise.

1 Experts excel in generating the best solution and can do this faster and more accurately than non-experts.
2 Experts can detect and see features that novices cannot, and can also perceive the 'deep structure' of a problem or situation.
3 Experts have more accurate self-monitoring skills in terms of their ability to detect errors and the status of their own comprehension.
4 Experts are more successful at choosing the appropriate strategies to use than novices.
5 More than ten years' experience is a necessary but not sufficient condition (see, for example, Jääskeläinen 1996).
6 Development of talent appears to require enormously supportive social contexts.

Regarding the first characteristic, it should be mentioned that translation experts do not necessarily work faster than non-experts since translators are often solving ill-defined problems (as in the case of literary translation), which are characterised by the lack of a clear path to a clear solution. The sixth characteristic, it seems, has not been explored by translation process researchers.

16.4.4 Findings on translation difficulty

As noted earlier, two essential questions in translation difficulty research are what makes a text difficult to translate and how to measure the difficulty level of a translation task.

Campbell and Hale (1999) identified several areas of difficulty in lexis and grammar, that is, words low in propositional content, complex noun phrases, abstractness, official terms and

passive verbs, and explored universal translation difficulties as well as language-specific difficulties. Vandepitte, Hartsuiker and Assche (2015) found three factors that influence the difficulty level of a text: (1) metonymic constructions (e.g., *Music took him around the world*), which are more difficult to translate than non-metonymic counterparts; (2) the translator's foreign language competence level; and (3) translation directionality. The third finding corroborates Chang's (2011) eye-tracking study, which showed that inverse translation (in this case, from Mandarin Chinese to English) was more cognitively demanding than direct translation.

On the question of how to measure translation difficulty, there are three perspectives: (1) translation-specific problems (or target-text characteristics); (2) readability (or source-text characteristics); and (3) translator factors. Campbell and Hale (1999) assessed the difficulty of a source text by Choice Network Analysis (Campbell 2000); that is, to count the number of different renditions for specific items in that text made by multiple translators. This method works under certain circumstances. Readability-based measurements use readability formulas (e.g., Flesch Reading Ease formula); they are objective and consequently can be performed automatically. In an empirical study, Sun and Shreve (2014, see Section 16.6 for details) found that a text's readability only partially accounts for its translation difficulty level. Techniques for measuring mental workload can be classified into three major categories: (1) subjective measures, (2) performance measures and (3) physiological measures. Performance measures (including time-on-task and translation quality score), Sun and Shreve (2014) found, were not very reliable. As a physiological measure, gaze time and fixation count using eye-tracking have been used as an indicator of cognitive load (Mishra et al. 2013). The baseline measure, according to Jex (1988: 14), is the individual's subjective workload evaluation in each task, against which all objective measures must be calibrated.

16.5 Main research methods

For expertise research, Ericsson and Smith (2002) proposed three steps: (1) finding or designing a collection of tasks to capture the superior performance in the specific domain; (2) applying various methods to examine the phenomena associated with a particular type of expertise; and (3) accounting for superior performance by experts. In the second step, research methods for studying the structure of expertise (i.e., components of competence) include observation of work practices in natural settings, psychometric approaches, laboratory methods, task analysis, protocol analysis and simulation for performance and training, while methods for investigating the acquisition and maintenance of expertise include laboratory methods, retrospective interviews, diaries, historiometric methods and others (see Ericsson et al. 2006). These methods can be combined, and most of them have been adopted in TPR.

According to Ericsson (2006), the complexity of the knowledge and skills of experts in most domains makes it practically impossible to describe the complete structure of an expert's expertise, so researchers should focus on the reproducible structure of the experts' mechanisms that mediate their superior performance on representative tasks. In order to do this, process tracing is often required to uncover detailed information about such mechanisms. Process tracing techniques include protocol analysis (especially TAP), screen recording, keystroke logging, eye-tracking, etc.

16.5.1 Protocol analysis

The method of protocol analysis is mainly based on Ericsson and Simon (1993), who have provided substantial empirical support for the theory that verbal protocols can be used to elicit

data on cognitive processes. There are two types of verbalisation (or verbal reports) that can be used to look into thoughts and their sequences: concurrent and retrospective verbalisation. The former is the recommended method for getting participants to verbalise their thoughts concurrently (i.e., thinking aloud) while performing a task. The latter is conducted immediately after the task is completed, as retrieval cues in short-term memory allow effective retrieval of the sequence of thoughts. Verbalisations of the participants are usually recorded on audio and transcribed, and the transcriptions (i.e., protocols) are then analysed. Both types of verbalisation have been used in TPR.

To date, there is no strong evidence suggesting that TAP significantly changes or influences the translation process. In a recent study, Pike et al. (2014) measured the effect of TAP on workload using a brain sensing technique (fNIRS). They found that the use of TAP was fine as long as the verbalisation used words related to solving the task and that there were no differences in task performance or mental workload between the silent baseline and TAP conditions. The empirical study by Jakobsen (2003) showed that thinking aloud delayed translation by about 25 per cent; no significant effects on revision were found; thinking aloud forced translators to process text in smaller segments. These findings were basically consistent with Ericsson and Simon's theory (see Sun 2011). An implication is that protocol analysis cannot be used to study chunking (or segmentation) or temporal critical behaviour in regular translation. It is for looking into thoughts and their sequences. In protocol analysis, researchers can treat the protocols as qualitative data and use techniques such as content analysis to interpret meaning from the content.

16.5.2 Keystroke logging

As a process tracing technique, keystroke logging involves the use of a software program that records such overt behaviour as keyboard actions (e.g., deletions, cut and paste operations), cursor movements and pauses during text production on a computer. Such a program usually has a replay function that allows the researcher to observe the writing or translation process and elicit a retrospective report on the task if need be. Specifically, a typical keystroke logging tool (such as Translog) can record time (total task time, time spent in the orientation, drafting or revision stages), pauses (their frequency, duration and positioning), text production units (their number and lengths) and revision actions (the number, nature and timing) (Saldanha and O'Brien 2013: 133). The data generated often can be transformed into numbers and used in correlational analysis (e.g., between a process feature and the quality of the target text).

Three major keystroke logging programs are ScriptLog, Translog and Inputlog (see Leijten et al. 2015). Of these programs, Translog is the one tailored for translation process research. Its recent version, Translog-II (Carl 2012), consists of two main components: Translog-II Supervisor (used to create a project file and to replay recorded sessions) and Translog-II User (used to run a text production experiment). The latter has source- and target-language windows, and activities that happen within the Translog interface are recorded. Any activity outside the Translog interface such as visiting websites is not recorded. In comparison, Inputlog records all keyboard and mouse events in Microsoft Word, Internet browser and other Windows-based programs. Translog can be used in combination with an eye-tracking program, while Inputlog also supports voice recording, thus enabling the integration of verbal reports.

16.5.3 Eye-tracking

Eye-tracking is the process of recording the point of gaze and the movement of the point of gaze via an eye-tracker. It can measure eye movements such as gaze time, fixation counts, fixation

durations, pupil dilation, blink rate and scanpath similarity. A fundamental assumption in eye-tracking research is the eye-mind hypothesis (Just and Carpenter 1976, 1980), which posits that 'the locus of the eye fixations reflects what is being internally processed' (1976: 471) and 'the eye remains fixated on a word as long as the word is being processed' (1980: 330). Based on the assumptions that longer gaze time corresponds to an increased level of cognitive processing and that the number of fixations is related to the number of components that an individual is required to process, eye-tracking metrics have been used to measure cognitive load in various tasks, such as reading for comprehension vs. reading for translation.

Compared with TAP, keystroke logging and eye-tracking are less intrusive, and scarcely interfere with the translation process in terms of speed or extra demand on participants' cognitive resources. Yet, these two techniques only allow the researcher to make inferences about the translation process and often cannot help figure out what is really going on in the participants' minds. If, for example, a participant's mind wanders during translation, the keystroke and eye-tracking data would be misleading. Thus, it has been recommended by researchers (e.g., Shreve and Angelone 2010) to combine different methods in a study to triangulate findings.

16.6 A case study

Translation process research typically adopts an empirical approach, which entails the collection of data from observation or experiment. This section presents a case study based on Sun and Shreve's (2014) experiment.

The purpose of that study was to find a method to measure difficulty in a translation task. It focused on the following research questions:

1 Whether NASA-TLX (Task Load Index), a multidimensional scale that includes six workload-related subscales (i.e., mental demand, physical demand, temporal demand, satisfaction in performance, effort and frustration level), is a reliable subjective metric for measuring translation difficulty.
2 Whether translation quality scores (i.e., accuracy) or time on task (i.e., speed) as a performance indicator can be used to measure or represent translation difficulty.
3 Whether Flesch Reading Ease formula (or readability formulas in general) can be used to predict a text's level of translation difficulty.
4 How we can know a text's level of translation difficulty for a translator without having the text translated first.

One hundred and two Chinese translation students participated in the study in 2011. Each participant translated six passages (two easy, two medium and two difficult) from English into Chinese on paper in two sessions with a week's interval between them. Each passage was about 130 words long. In the test, a participant read a passage, did the pre-translation rating on a 0–10 scale, translated the passage, and then did the rating on NASA-TLX after the translation.

It was found that NASA-TLX could be used to assess translation difficulty for the translator and was proved to be reliable. Translation quality score was found to be an unreliable indicator of translation difficulty level as measured by NASA-TLX, while time-on-task was significantly, but weakly, related to translation difficulty level. A text's readability only partially accounted for its translation difficulty level. A formula was developed using multiple regression to predict a text's translation difficulty level for a translator by using the translator's pre-translation rating. It was supposed to facilitate future studies.

In China, as noted earlier, most empirical studies have been done by MA and doctoral students. Limited by funding, access to and knowledge of equipment (e.g., eye-trackers), TPR still stays in the initial phase of development, featuring the predominant use of TAP, small samples and lack of rigour in research designs. Things are changing. In recent years, research funding in the humanities and social sciences has been on the rise, and training in research methods in TPR is increasing. The University of Macau, for instance, established a Centre for Studies of Translation, Interpreting and Cognition in 2014, and holds an international conference on TPR annually. For Chinese researchers, replication with, say, a different language pair (including Chinese) and the same text, can be conducted to validate or falsify hypotheses or theories put forward based on language pairs that do not include Chinese. It would be a good start. In this regard, knowledge in Chinese psycholinguistics (e.g., Chinese-reading eye movements, see e.g., Huang et al. 2014) may relate to some empirical considerations in TPR.

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Further reading

Ferreira, Aline and Schwieter, John W. (eds.) (2015) *Psycholinguistic and Cognitive Inquiries into Translation and Interpreting*. Amsterdam: John Benjamins.
This volume provides a recent introduction to some major topics in TPR.

Saldanha, Gabriela and O'Brien, Sharon (2013) *Research Methodologies in Translation Studies*. Manchester: St Jerome.
This book presents a comprehensive review of research methods (including those in TPR) used by translation researchers.

Shreve, Gregory M. and Angelone, Erik (eds.) (2010) *Translation and Cognition*. Amsterdam: John Benjamins.
This volume focuses on methodological innovation and research design issues in TPR and on the integration of TPR results with findings of cognitive sciences.

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