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Studies on the Mental Processes in Translation Memory-assisted Translation – the State of the Art

Abstract

This article reviews research on the mental translation processes involved in translation memory-assisted translation. First, based on recent developments in cognitive science the article provides a working definition of mental TM research. Next the article analyses a selection of mental TM studies with a view to discovering their aims, data, methods and results. In doing so, the paper attempts to find out what we know by now about the mental aspects of translation memory-assisted translation. The analysis suggests fruitful avenues for future research and concludes that particularly more research is needed which takes into account the recent developments within TM technology and looks into both internal and external translation processes.

1 Introduction

Translation-memory (TM) tools, which nowadays are used by most professional translators (Lagoudaki 2006), are expected to impact on translators' mental translation processes and workflow (Biau Gil/Pym 2006: 9; Mossop 2006: 790; Garcia 2007: 56), and yet the mental changes imposed by TM technology have not been the object of much research. Moreover, research into the mental processes of translation is hampered by insufficient theoretical and methodological underpinning (Campbell/ Wakim 2007: 271). The present article wants to help fill this research gap by discovering which research designs have been applied so far to investigate mental aspects of TM-assisted translation and what knowledge has been gained from these studies. Section 2 presents a cognitive view on TM translation as a mental activity and provides a working definition of mental TM research. Taking its starting point in Krings (2005), section 3 makes an outline of methods generally employed in translation process research. Based on this outline, section 4 analyses empirical research studies carried out on mental TM translation with a view to discovering their aims, data, methods and results. Section 5 concludes the paper with a summary of what has been found and suggests future directions for empirical research on mental TM-assisted translation processes.

2 TM-assisted Translation as a Mental Activity

In TM-assisted translation, the translation is carried out by a human translator, but computer assistance is an integral part of the process (Alcina 2008). Basically a TM is a database of previous translations by means of sentences or sentence-like units called segments. When a new text is to be translated, the database automatically compares the character chains of each new source text segment with character chains stored in the database and provides the translator with different types of TM matches (e.g. exact matches, fuzzy matches and no matches). Today typically translators log in to the database via their browser and interact with an online (server-based) TM. In this web-interactive mode, the TM can leverage segments in real time as and when they are created by other translators working remotely on the same project (Garcia 2009: 203). This means that TM systems can be used both by individual translators and by teams of translators collaborating on the same or related texts. Worth noting is, that increasingly TMs comprise a machine translation (MT) component, which enables automatic translation if no match can be retrieved. This is termed "MT-assisted TM". According to Garcia (2010: 19), the next trend in the translation industry will be "TM-assisted MT" (e.g. the Google Translator Toolkit), in which the translator would work on an MT editor. For a detailed description of various aspects of TM technology, see Christensen and Schjoldager (2010).

In the following I will provide a cognitive view on TM translation in order to be able to come up with a tentative definition of mental TM research. Theories within cognitive science deal mainly with the internal processes that occur during human action. The human action carried out by a translator is generally speaking the action of producing a target text based on a source text. This activity is covered by the notion of translation process. Research investigating the translation process has generally focused either on the workflow and cooperation or on translators' mental processes (Göpferich 2008: 1). According to Schubert (2009: 19), the former looks into the external and the latter into the internal process. Schubert defines the internal process as the mental activity involved in carrying out the translation work with all its steps and decisions which are not open to direct observation. Due to this, mental processes are often referred to as 'the translator's black box'. External processes cover everything in the translation process which can be observed by another person. According to Göpferich (2008: 1) mental processes can be divided into conscious and subconscious processes. The former are referred to as cognitive processes, which with a view on the individual translator constitute the central aim of translation process research (Englund Dimitrova 2010: 406). As suggested by Göpferich (2008: 1), the ability to reflect on one's own mental processes may be described as metacognition. Broadly defined, metacognition is any knowledge or cognitive process that refers to monitoring and controlling any aspect of cognition, or simply, thinking about cognition. Metacognition usually precedes or follows a cognitive activity. However, they are closely intertwined, because they may overlap during processing (see Flavell 1979). It is worth noting that also internal and external processes are interrelated. Internal processes take place within external

workflows (Schubert 2009: 19), which means that internal processes are influenced by external processes. In other words, external processes guide, constrain, and even determine cognitive behavior (Zhang 1997: 180 cited in Dragsted 2006: 445; Göpferich 2008: 14). Also translators' observable actions must be expected to have a counterpart in translators' internal processes.

Following cognitive science, cognitive processes are processes that are involved in memory, decision making, inference, reasoning, learning, and so on (Hutchins 2000: 1). Hence, cognitive translation process studies contribute to the knowledge of how the translator's mind functions when performing the complex task of translation (Risku 2010: 94). Viewing translation as a writing activity, cognitive translation processes may be categorised as belonging to one of three phases being transformed under the influence of a series of information processes: (1) planning, (2) drafting and (3) post-drafting (Jakobsen 2003). The phases are listed in a linear way, but as Breedveld (2002: 93f.) notes, the process as a whole should be seen as a recursive and reiterative process, in which different sub-processes do not occur in a fixed order, but are dominant at different moments throughout the processes.

It is assumed that information processing takes place in different buffers: the sensory register (SR), the short-term memory (STM), and the long-term memory (LTM). In the SR, all information is encoded into an internal form and is stored very briefly. Of this information only a small amount enters into the STM by means of attention. The STM is limited in capacity and duration (15-20 seconds). From here information in the form of elaboration will attain to the LTM that stores all information which is not immediately used. Like all cognitive processing, translation embraces two aspects of language performance: automated processes on the subconscious level and non-automated processes on the conscious level (Gabryś-Barker 2009: 26-33). According to Ericsson and Simon (1984: 11), individuals are only conscious of the processes taking place in the STM. When the individual needs information stored in the LTM, the information is retrieved from the LTM and then activated in the STM.

Taking into account that cognitive processes are determined partly by external processes, the latest trend in cognitive science is to no longer see information processing as an activity taking place exclusively inside the individual human's mind, but as interplay between human mind, body and situation/environment. The primary concern of the so-called Situated, Embodied Cognition paradigm is the fact that the individual and the present environment form an integral part of the processes of thought and behavior (Risku 2010: 99). In effect, it is assumed that humans also think by carrying out physical, epistemic actions, ordering and reordering the environment and changing their focus of perception and attention through eye and body movements (Risku 2010: 99). According to Risku (2010: 103), any attempts to explain translation by describing processes in the mind of an individual alone are bound to fail. What we need to do is to combine investigations on what happens in a translator's mind with what happens elsewhere, e.g. in translators' hands, in their computers, on their desks, in their work environment and in their dialogues and interactions with their collaboration

partners. In other words, we need to focus on the relationship between the mind, the body, artifacts, and the social environment. The cognitive relationship between humans and artifacts is highlighted in the Distributed Cognition paradigm (Hutchins 2000), which consider cognition as a distributed phenomenon across individuals and across internal and external representations, which are termed artifacts. According to Hutchins, artifacts are defined as things that make humans smarter and are parts of a distributed cognitive process.

A TM is to be considered a material artifact involved in the human translator's process of organizing the functional skill of memorizing translation decisions made during earlier translations into cognitive functional skills. In other words, a TM constitutes a supplementary LTM from which information can be retrieved. When groups of translators use a TM, they can be said to share cognitive resources via the artifact. Hence, this is an example of what we could call collective distributed cognition. When individual translators use a TM in order to reuse their own previous translations, then the cognitive task of translating is simply distributed between the translator and the artifact (Dragsted 2006: 444). Being an instance of distributed cognition, TM-assisted translation is assumed to interfere with and control translators' mental processes. This is mainly due to the fact that a TM automatically provides the translator with translation proposals, which the translator is forced to consider before moving on. In fact, a TM can be said to offer solutions also when the translator is not aware of facing a translation problem. Having to consider and assess the retrieved matches, translators may indeed spend more time thinking about and revising previous translations than they do translating from scratch (Garcia 2010).

Based on the cognitive perspective on TM-assisted translation introduced above, in this paper mental TM research is operationalised as studies which look into certain aspects of translators' information processing during TM-assisted translation which are not directly observable by humans or studies which investigate translators' external processes within which these internal processes take place if the external processes are explicitly related to the internal processing. Hence, studies investigating, for instance, translation products (e.g. the content of TM databases) are not considered mental TM studies, even though the products are recognised as results of internal processing (e.g. Torres-Hostench et al. 2010). Moreover, studies are not regarded as mental TM studies, if they focus on external translation processes alone (e.g. Désilates et al. 2009) or investigate aspects which could be related to internal processes (e.g. productivity or quality), but which in the particular study have not been (e.g. Bowker 2005; Guerberof 2009; Yamada 2011).

3 Research Methods in Translation Process Research

To be able to determine which research methods have been applied in mental TM research so far, this article takes its starting point in Krings' (2005) model of the basic methods applied in translation process research (Fig. 1).

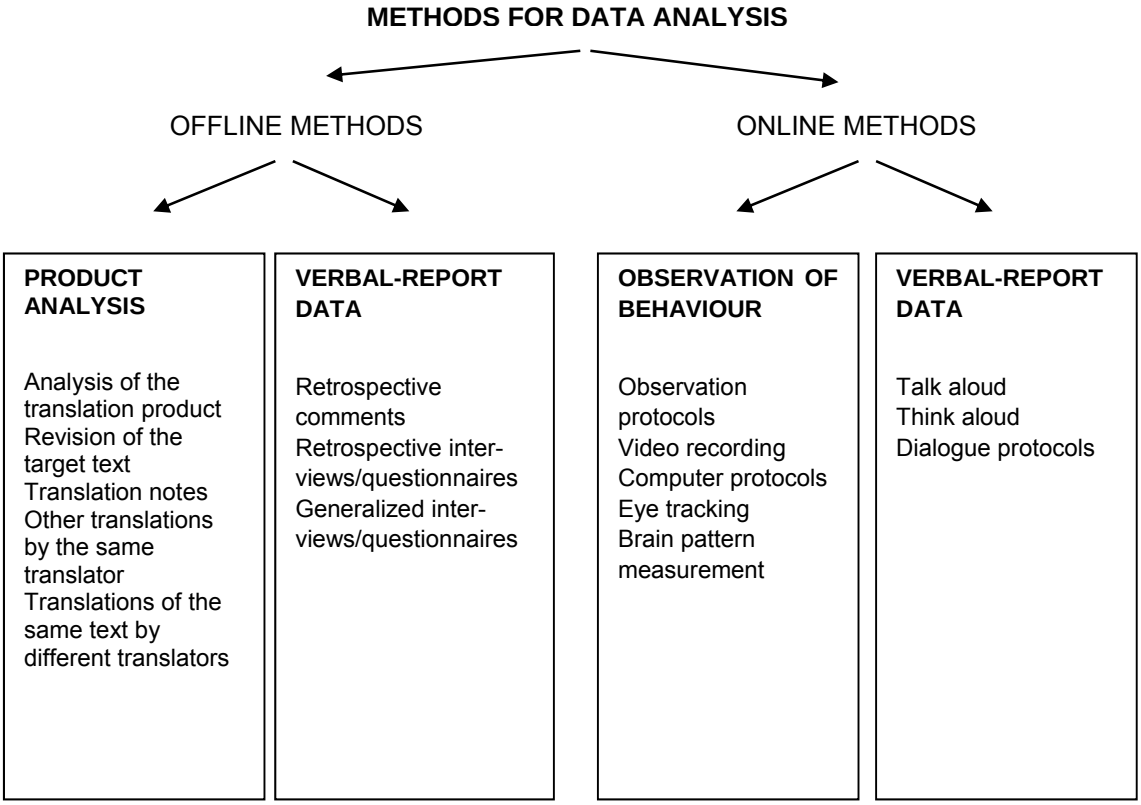

Fig. 1: Basic methods for data analysis (Krings 2005: 348, translated by Dam-Jensen/Heine 2009: 3)

The model distinguishes between offline and online methods. Offline methods cover methods in which data are collected after the translation process. These methods are divided into product analysis data and verbal report-data. In online methods, data are produced during the translation process. Online methods cover data collected by way of observation of the translation process and verbal-reports. Below the four categories of research methods and their inherent strengths and weaknesses are presented in order for the reader of this article to be able to assess the usefulness and validity of the findings of the research studies to be analysed in this paper.

3.1 Product Analysis

Product analysis may be carried out by means of e.g. *analysis of the translation product*, *revisions of target texts*, and *translation notes*. Logically, the translation product forms an inherent part of the translation process, however, product data only allow speculation about the underlying mental processes (Hébert-Malloch 2004: 976; Englund Dimitrova 2005: 37; Krings 2005: 348; Göpferich 2008: 9).

3.2 Observation of Behaviour

Methods for observation of behaviour make it possible to register observable aspects of the translation process. Krings (2005) distinguishes the following methods: *observation protocols*, *video recording*, *computer protocols*, *eye tracking*, and *brain pattern measurement*. Arguably, all methods apart from observation protocols do not constitute research methods as such, but simply use particular tools and techniques which provide information about specific observable aspects of the translation process.

Using *observation protocols*, the researcher observes the translator on-site while translating and notes all audible and observable actions. According to Krings (2005: 350), this kind of observation is practically no longer practiced in translation process research. According to Claney (2006) observation protocols are, however, still being used in field studies. A more sophisticated way to observe the translation process is observation by means of *video recording*. Positioned in front of the translator, the camera may register the translator including his/her facial expressions and gestures. Applying an (additional) camera placed behind the translator, translation activities and other activities within camera range, e.g. dictionary or internet searches, can be recorded (Krings 2005: 350). So, like observation protocols video recording makes it possible to register those processes which can be observed by another person. The obvious shortcoming of these methods is that they do not allow a glimpse into the translator's mind while translating. Thus the cognitive processes underlying the observable activities must be interpreted by the researcher. This might be difficult, because observational data can be ambiguous. Consequently, in mental studies, data from these methods should be used primarily as a source of inspiration for retrospective interviews or to interpret data obtained by other methods. *Computer protocols* include *keystroke logging* and *screen capture*. These methods apply computer software which registers how the entire translation process is carried out on the computer screen (Krings 2005: 350). *Keystroke logging* records subjects' keyboard and mouse actions, i.e. which keys are activated and for how long. In translation process studies, keystroke logging has been used mainly to obtain information on pausing and timing in text production (Alves/Concalves 2003; Dragsted 2004, 2006; Hansen 2006; Jakobsen 2006). For an overview of keystroke logging software see Göpferich (2008). Translog (Jakobsen: 2006) is an example of keystroke logging software designed to display a source text in one window in the top half of the screen and to allow a target text to be written in another window in the bottom half of the screen. Text editing takes place in a standard Windows environment. At the end of a translation session, the actions are saved in a logfile. Based on this, Translog generates a data set that can be analysed quantitatively, and a replay function makes it possible to review the entire typing process, and in another window, a linear representation of the typing process. A shortcoming of this method is, however, that it can only log translators' interactions with one program at a time. Applying *screen capture*, everything that can be seen on the screen during the translation process is registered as a movie file that can be replayed at different speeds and be analyzed with an analysis tool that provides a graphical user

interface for encoding the recorded movie (Degenhardt 2006: 183). In addition, the translator's verbal utterances during the process are recorded. Camtasia Studio and Clearview are examples of screen capture software. Interestingly, screen capture software allows the utilization of more than one program, or file, in parallel, and the search in the WWW, for instance. A shortcoming of this software is that it does not indicate the part of the exact chunks of texts or pictures on which subjects focus when looking at the screen. Due to this it might be useful to combine screen capture with eye tracking. *Eye tracking* is a method for examining how translators' eyes move through a digital text, i.e. how translators read (and understand) texts. Today, the most used eye tracker is a device with infrared diodes that reflect the light of the pupil and monitor fixations, gaze path and pupil size as the subject interacts with an object-on-screen (O'Brien 2009: 252). These eye trackers are integrated in a screen. Hence, the subject can work without being affected physically by the device. However, these eye trackers must be calibrated to the subject's individual eye and the subject must stay within the visual angle of the eye tracker while translating (Göpferich 2008: 56). Another methodological problem is that some subjects' eyes cannot be traced reliably (Jacob/Karn 2003: 578) and that an eye tracker is unable to register all parts (e.g. menu bars and scroll bars) on the screen (Dam Jensen/Heine 2009: 7). When used in translation process research, eye tracking has been used to disclose translators' visual attention during the translation process, for instance. The question is, however, how fixation patterns are to be related to cognitive activity. Researchers generally apply a top-down strategy based on cognitive theory which means that they choose some dependent eye tracking variables as indicators of a particular cognitive effort (e.g. O'Brien 2006, 2008). Medical data gathering tools (e.g. EEG, MRI and PET) allowing for *brain pattern measurement* can be used to investigate which parts of the brain are being activated during translation and the intensity of this activity (e.g. Grabner et al. 2007). A shortcoming is that it is difficult to determine exactly which mental processes and thoughts cause an activation of a particular part of the brain (Göpferich 2008: 11). The medical techniques have yet to be widely adopted in translation process research; for an overview see Diamond and Shreve (2010).

To sum up, video recording and observation protocols can register translators' external processes, whereas the computer software tools offer a way to look into translators' internal processes. However, it should be taken into account, that all observational methods are supposed to influence translators' behavior, because subjects might feel observed; even when the tool (like screen capture) is not visible to the translator (Degenhards 2006: 180; Geisler/Slatery 2007: 187).

3.3 Offline and Online Verbal-report Data

Data gathered by means of subjects' verbalisations about thoughts, feelings, attitudes, etc. (Krings 1995) are termed verbal-report data. According to Ericsson and Simons (1984), verbalisations take place on three levels of thought processing: The level of verbalisation/articulation (level 1), the level of description of the content (level 2), and

the level of explanation including interpretation of thoughts (level 3). Level-1 verbalisations are to a high degree assumed to be consistent with the underlying mental processing, i.e. reflecting cognition, whereas level-2 verbalisations are likely to constitute both cognition and metacognition (Göpferich 2008: 26). Assumingly, level-3 verbalisations constitute metacognition. Krings distinguishes between offline and online verbalisations. Offline verbalisation covers immediate and delayed retrospection. Online verbalisation covers concurrent introspection if we regard introspection and retrospection as complementary concepts (Krings 1995; Göpferich 2008: 16). The assumption underlying all verbal-report methods is that each verbalisation comes from the cognitive process that underlies it. When online methods are used, the verbalisation processes reflect the cognitive processes directly, because information stored in the STM is utilized concurrently with performing the task. In contrast, offline methods reflect the cognitive processes indirectly, because the information is retrieved after the task (Gabryś-Barker 2009: 27). What they have in common is the fact that subjects can only verbalise conscious processes, and subjects are only conscious about the processes taking place in the STM. If for instance translating with a TM has become a routine, these automated processes can be carried out without the intermediate steps being processed in the STM (see Ericsson/Simon 1984: 15; Kovačič 2000: 98). Hence, these automated processes are not accessible via verbalisation (García Álvarez 2007: 141; Göpferich 2008: 18f.).

In Krings' (2005) model, offline verbal-report data methods cover *retrospective comments*, *retrospective* and *generalized interviews* and *retrospective* and *generalized questionnaires*. According to Englund Dimitrova and Tiselius (2009: 109), the number of studies for which retrospection has been used as a direct source of data is quite limited. In translation process research, *retrospective comments* are most likely to be used to obtain qualitative data, which can help interpret data collected by means of other methods (O'Brien 2006; Alves/Liparini Campos 2009; Pavlović 2009). Often retrospective comments are obtained by means of media-based retrospection where subjects are shown a video of their translation process (e.g. writing activities) in order to help them remember their process (e.g. Hansen 2006). *Retrospective interviews/ questionnaires* cover questions relating to a specific translation task, whereas *generalized questionnaires/interviews* cover questions relating to general translation strategies of translators (Krings 2005: 349). If subjects complete the questionnaire with the researcher not present, these are referred to as postal or online questionnaires. If subjects are asked to complete the questionnaire by verbally responding to questions in the presence of the researcher, this is called a structured interview. Both variations ask closed or open questions. A closed question is a question for which a list of responses is provided; hence this procedure produces mainly quantitative data. Applying open questions, the subjects are asked to think and answer a question in their own words. Consequently, this procedure produces mainly qualitative data. When questionnaires are used in translation process studies, they typically are applied to obtain background information on the subjects, e.g. in order to be able to select

appropriate subjects (e.g. Torres-Hostench et al. 2010) or as post-experimental retrospective questionnaires on certain translation aspects. These aspects typically relate either to the translation product (e.g. O'Brien 2006, 2008) or the translation process (e.g. Dragsted 2004, 2006; Christensen/Schjoldager 2011). A shortcoming of all kinds of offline verbal data is that subjects verbalise their translation processes retrospectively, which means that subject must retrieve information from the LTM. The time delay of the verbalisation act involves the risk that translators are not verbalising the cognitive process, but simply infer what they must have thought or construct new explanations (Sullivan/Lindgren 2006: 156). In fact, several experiments have shown that subjects give explanations with are inconsistent with their observed behavior (Ericsson 2006: 227). Hence, offline verbal-report data might be of low validity (Hansen 2005: 519; Krings 2005: 349). An advantage of offline data is that they do not interfere with translators' mental translation processes.

Methods for obtaining online verbal-report data are *think aloud*, *talk aloud* and *dialogue protocols*. *Think aloud* or *talk aloud* (both are abbreviated as TAPs) cover methods where subjects carry out the translation task alone. If two subjects are asked to carry out a translation in collaboration, the data are obtained by way of *dialogue protocols*. In all three approaches subjects' verbalisations are audio and/or video recorded and then transcribed in so-called protocols. In think aloud, subjects verbalise their thoughts nonselectively and spontaneously while translating. This means that subjects' verbalising processes take place simultaneously in the STM and, thus, that extra cognitive demand might be placed on subjects. Several TAP studies have found that TAPs interfere with subjects' underlying mental processes (e.g. House 2000: 152) and that TAP data are not necessarily identical with the underlying cognitive processes (Jääskeläinen 2000). Still, think aloud is the most frequently used online verbal-report data method in mental translation process studies (Hébert-Malloch 2004: 973; Krings 2005: 351; Jakobsen 2006: 95). Talk aloud, which is a kind of reduced think aloud because subjects only verbalise those thoughts which they also in a non-experimental setting would address loudly to themselves (Krings 2005: 351), is very seldom used.

What all verbal-report methods have in common is that they generate metacognitive data because subjects are asked to think about their cognition. Only if subjects are asked to produce level-1 verbalisations applying online methods, is it possible to obtain verbalizations that can be regarded as instances of cognition.

4 Review of Empirical Studies on Mental TM Translation

In the following we shall concentrate on finding out which research designs have been applied in mental TM research studies by studying a selection of empirical TM studies. The studies were mainly found by means of bibliographical references of TM literature and via a search for publications in online bibliographical databases. Since TM technology was not common until the turn of the millennium, only studies published in 2000 or

later are included. Apart from this, only publications fulfilling the following three criteria were selected:

(1) The topic is mental TM research, which is operationalised as studies which fulfill the definition criteria of mental TM research (see section 2).
(2) The publication is a research report by means of a knowledge-oriented type of study aimed at describing, explaining and/or predicting a given phenomenon (Vandepitte 2008: 574) and is published within the academic world, i.e. primarily aimed at academics as opposed to being aimed at the profession (Christensen/ Schjoldager 2010).
(3) The study is empirical, which is defined as a study analysing data.

As a result of the search for empirical studies fulfilling the above criteria, I could identify five studies (some of them reported in more than one publication). Here the studies, presented in chronological order, are reviewed with a view to discovering their aims, data, methods, and findings.

Dragsted (2004, 2006) investigates whether the sentence, which is the segment-level applied by most TM systems, constitutes translators' 'normal' cognitive translation unit and whether the use of a TM impacts on the extent to which translators change the source-text sentence structure and translators' revision time. The study comprises data from two experiments involving six professional translators (with at least two years of professional experience) and six students (in their final year of MA studies of specialised translation). In one experiment, Dragsted studies pure human translation registering the process with Translog. Based on these quantitative data, Dragsted determines how subjects segment (indicated by subjects pausing) texts while translation without a TM. In another experiment, the subjects translate a text using a TM (Trados). Immediately after the translation tasks, subjects are asked about their perception of their behavior and the text they had translated or their perception of working interactively with a TM and the division of the text into sentences, respectively. Whether the retrospection was carried out by means of an interview or questionnaire is not clear. Product analyses of subjects' target texts are used to investigate whether subjects are less inclined to change the sentence structure when using a TM. Dragsted's findings suggest that the sentence does not constitute a central unit in translators' mental segmentation: when translating without a TM the translators appeared to work primarily with either clauses or phrases, though this may be truer for professional translators than for students. Both groups were less inclined to change the sentence structures of the source texts during TM translation. The non-professionals found that the TM facilitated the process because of its focus on sentences, whereas the professionals found that this type of segmentation complicated their processing. Furthermore, it was found that the use of a TM reduces the time spent on revision in both groups, thus making them more inclined to revise the target text sentence by sentence rather than in the end-revision phase.

O'Brien (2006, 2008) investigates translators' cognitive load in connection with various TM match types. Here I will report only on the study from 2008. O'Brien (2008) carries out an experiment in which eight translation students (in their final year of an undergraduate translation degree or in their first year of an MA) translated a technical text using a TM (SDL Trados Translator's Workbench) in order to investigate the relationship between fuzzy match values and cognitive effort. The cognitive effort is measured using processing speed (words per second) recorded by screen capture technology (Camtasia) and pupil dilation recorded using an eye tracker (Tobii 1750). Because only five subjects' eye movements could be accurately tracked, the study was limited to these five. Once the subjects had finished the translation task, they were shown a paper-based questionnaire that included the same source segments and fuzzy matches (but not the fuzzy match values) that they had just seen on the screen. Subjects were asked to rate their perceived editing effort for each match using a five-point scale. Applying processing speed as a measure, the findings suggest that the lower match values require more cognitive effort than the higher match values. Interestingly, it is found that the difference in processing speed between the 60-69 % match class and the 50-59 % match class is small. Using pupil dilation as a measure, the study found that dilation increases as match value decreases until the 60-69 % match class is reached. Below this match class, decreased pupil dilation is noted. According to O'Brien, this might be due to the fact that subjects reached a baseline of cognitive effort. The survey data show that subjects rate segments between 80 and 99 % as requiring little effort, while anything between 50-79 % is seen as requiring more editing effort. However, also instances of disconnection between fuzzy match value and translators' perceived editing effort could be found. O'Brien's study is a best practice example of how methods can be mixed in order to investigate a certain aspect of TM translation from different vantage points.

Alves and Liparini Campos (2009) aim at investigating how the use of a TM (Trados Translator's Workbench 7) and time pressure impact on which types of support (internal and external support) translators use when they pause. The underlying assumption is that translators pause in order to orientate themselves or to revise the translation produced so far in all cognitive sub-phases of the translation process. Because a pilot study had shown that orientation seldom occurs as a separate phase, the study focuses on the drafting and end-revision phase. By internal support is meant strategies which imply the use of automatic and non-automatic existing cognitive resources, and external support covers strategies which involve the use of any source of documentation to make up for information which is not immediately available to the translator. Internal support is divided into simple internal support (the translator does not carry out any kind of search) and dominant internal support (the translator looks up one or several external sources, but the translation choice made is not provided by this or these sources, or the translator pauses in order to think about a TM suggestion, independently of accepting it or rejecting it). External support is divided into simple external support (the translator looks up a single external source, such as a dictionary

or a website), and dominant external support (the translator initiates a complex source and accepts one of the suggestions provided, or the translator activates the Trados Concordancer). In the study, 12 professional translators with at least 6 years of professional experience and two years' experience with TM were asked to carry out four translation tasks: (1) without aids, (2) with a TM, (3) under time pressure, and (4) with a TM and under time pressure. Translations performed without the use of a TM (task 1 and 3) were recorded with Translog, and translations carried out using a TM (task 2 and 4) were registered with Camtasia. Furthermore, onsite-observation on the translators' consultation of external sources was carried out using pre-elaborated observation charts. After the translation tasks, subjects were asked to comment on their translation processes by replaying their work processes either with Translog or Camtasia. As regards data analysis, pauses of five seconds or longer were classified replaying the translation process with Translog or Camtasia. In Translog, pauses can be identified automatically, whereas in Camtasia pauses must be identified by replaying the recordings and manually defining the pauses using the clock provided by the software. In order to classify types of support used, the Translog or Camtasia files were replayed again. These data were combined with data from the observation charts and observation protocols. These supplementary data were instrumental in determining the type of support used during task 1 and 3, whereas when analysing the data from task 2 and 4, the data were only used to confirm the Camtasia data. The study found that in the drafting phase, in all four experimental situations, orientation pauses are by far more frequent than revision pauses and the most prevalent type of support is simple internal support in all experiments but one: translation with a TM. Compared with non TM-assisted translation, the use of a TM increases the number of orientation pauses (from 70 to 79 %) and changes the type of internal support used from being mainly simple internal support (from 59 % to 31 %) where no sources are used to being mainly dominant internal support (from 1 % to 38 %) where TM proposals are used as internal stimulus. This is considered a direct result of the impact of the TM system, because when the TM offers the translator a translation alternative, the translator is automatically led to consider the suggestions before moving on. As for the types of pauses and support used during the end-revision phase, the findings suggest that orientation pauses are very rare in end-revision of all four translation tasks (between 0 and 6 %), which means that translators seem to check the target texts produced so far, and in doing so they predominantly (between 94 and 95 %) resort to simple internal support. Hence, in the end-revision phase the use of a TM did not impact on the types of support applied. The study is exemplary in that it provides a theoretical justification as to why certain analyses are done and it adopts a multi-method approach in doing so. The findings seem logical and probable, but a more elaborate discussion of why TM proposals are classified as an internal strategy while the use of the concordance feature is considered an external strategy would have been an additional asset because obviously both types of proposals are observable on the screen.

The exploratory study of *Christensen and Schjoldager* (2011) aims at analysing translators' reflections on mental TM processes and to explore the usefulness of post-experimental questionnaire data. The study includes 22 MA students taking an obligatory course in translation methodology and theory at the Aarhus School of Business. Based on their experiences in a hands-on course introducing them to SDL Trados 7, the students (response rate: 22 of 23) were asked to fill in a post-experimental online questionnaire immediately after they had participated in the course. The authors expected students without previous TM experience to be more likely to provide in-depth reflections on how a TM affects their mental translation processes than professional translators because TM translation has not become a routine to them. In the questionnaire, answers were given either in closed boxes (mainly for background information) or in open boxes where students were asked to write their thoughts about and reactions to what they had experienced during the course. The questionnaire data are combined with observation protocols by means of session logs recording all incidents occurring in the computer room during the course. The findings suggest that all 22 subjects find the translation process with a TM different from translating without a TM and say that TM technology is a useful, but at the same time deceptive tool. A TM is regarded as useful because TM translation is experienced as easier, more interesting, faster and more efficient. The subjects also argue that translations become more consistent and that the use of a TM allows the translator to easily draw on other people's knowledge. A TM is considered a deceptive tool because translators may lose control of the process, forget about the context, lose track of the text and the aim of the translation, focus too much on the source text, the sentence level and terminology, and lose their critical sense. They furthermore stress that translating becomes more mechanical, less personal, less creative, less functional, and revision becomes more important. Based on the high response rate and the depth and relevance of the respondents' answers, the authors conclude that the post-experimental questionnaire data obtained constitute metacognition on subjects' cognitive processes. The argument being that the subjects indeed did reflect on their mental translation process, the drawbacks and advantages of applying a TM, and how the TM affected their mental translation process. As the authors admit themselves, however, it may be construed as a methodological weakness that data are obtained as part of an academic course because students may tend to tell what they think the instructors wish to hear, the phenomenon referred to as participant bias (Saunders/Lewis/Thornhill 1997/2009: 156). Interestingly, several of the comments made by the students are documented by some of the empirical studies reviewed here and are also supported by anecdotal evidence about the effects of using a TM (e.g. Bowker 2005; Kenny 2007; Garcia 2009).

O'Brien et al. (2010) investigate the usefulness of sub-segment matching in a TM interface in a pilot study involving six professional translators with experience with the TM tool that was used (SDL Trados 2007). In the experiment, three translators translated a text with the concordance feature enabled; the other three with it being

disabled. The translation task, which was recorded by an eye tracker (Tobii 1750) which also included screen capture and keystroke logging, was followed by an interview including questions about e.g. a sub-segmenting feature called AutoSuggest. This feature is included in SDL Trados Studio 2009 and 2011. It offers predictive suggestions to translators as they type. The study tests the usefulness of the concordance feature measuring: (1) usage which is operationalised as number of eye fixations and duration of fixations on the concordance window compared with other windows (TM window and the edit window) and the number of direct cut and paste actions from the concordance window as well as the number of times translators reproduced the suggested content from the concordance window by direct typing it; (2) productivity which is operationalised as average task time length when the concordance feature was used versus its non-use; and (3) opinions by means of subjects' assessment of sub-segmenting features. In addition, the study investigates the final product quality using a standard localization quality assessment procedure (LISA QA Model). The findings suggest that translators indeed use the information provided by a concordance search and even give the sub-segment matches priority over the longer matches presented in the TM window. Comparing the task time for translation with the Concordancer enabled versus disabled, the use of the concordance feature seems to have a negative impact on productivity. Interestingly, at the same time a positive impact on quality was noted. The survey suggests that translators find the concordance feature useful for checking terminology and context, but also that they do not wish to have this feature turned on constantly. As for AutoSuggest, the translators found that this feature could be useful, but also that they would like to have the option of turning it off. Applying product data as well as process data, the study demonstrates how these can be used side-by-side to reinforce each other.

5 Overall Findings

Hoping to establish what has been documented so far by means of empirical studies on TM translation as a mental activity, I searched the TM literature at large and came up with a modest list of five studies. This list may not contain all available empirical studies of TM as a mental activity, but my assumption is that it may be seen as representative of mental TM research so far. Figure 2 below sums up the overall aims and the methods applied in the five studies. In brackets, I have mentioned what each method aims at studying. To facilitate reading of the next paragraph, the numbers in () refer to the studies mentioned in figure 2.

No	Study	Overall aim and methods applied
1	Dragsted (2004 and 2006)	*Aim: Impact of TM on human segmentation* ➢ keystroke logging (segmentation via pauses in human translation) + (time task length via processing speed) ➢ product analysis (sentence level processing) ➢ post-experimental interviews/questionnaire (subjects' reflections on their translation processes)
2	O'Brien (2008)	*Aim: Cognitive effort related to TM match type* ➢ eye tracking (cognitive effort via pupil dilation) ➢ screen capture (cognitive effort via processing speed) ➢ paper-based post-experimental questionnaire (subjects' perceived cognitive effort)
3	Alves and Liparini Campos (2009)	*Aim: Impact of TM on types of internal pauses and types of support* ➢ keystroke logging (types of pauses in human translation) ➢ screen capture (types of pauses in TM translation) + (types of support via pauses in TM translation) ➢ observation protocols (use of external support in human translation) ➢ media-based retrospective comments (types of support via subjects' reflections on translation process in human and TM-assisted translation)
4	Christensen and Schjoldager (2011)	*Aim: Metacognition on a TM's impact on translation process* ➢ post-experimental questionnaire (subjects' reflections on their TM-assisted translation process) ➢ observation protocols (room activity)
5	O'Brien et al. (2010)	*Aim: Cognitive usage/usefulness* ➢ eye tracking (cognitive usage via fixations) + (productivity via time task length) ➢ interviews (subjects' opinion on sub-segmenting features) ➢ product analysis (translation quality)

Fig. 2: Mental TM research – aims and methods

As can be seen from figure 2, the analysis of empirical research studies on TM translation as a mental activity suggests that this type of research may be divided roughly into two areas according to authors' interests and aims: those being interested mainly in investigating the impact of using a TM (1, 3 and 4) and those whose interest obviously lies with the core cognitive aspects of TM translation (2 and 5). In order to investigate whether a TM impacts on translators' segmentation, Dragsted (1) conducted an experiment in which translators translated without a TM and compared the findings from this experiment with the fact that TM systems apply a sentence-based segmentation. To investigate whether a TM impacts on how often translators change the sentence structure of source texts and on total revision time, she compared target texts produced

in the human translation experiment and target texts produced in a TM-assisted translation experiment and the total revision time in both experiments. To investigate whether a TM impacts on translators' types of pauses and types of support, Alves and Liparini Campos (3), collected data in four experiments in which translators were asked to translate with or without a TM and compared these data with each other. To investigate the impact of translating with a TM, Christensen and Schjoldager (4) collected retrospective verbal-report data in an experimental translation session where subjects were asked to translate a text with a TM. The choice of this research design was based on the assumption that when asked to comment on how TM translation differs from human translation, subjects which had not been using a TM before would compare the experimental TM-assisted translation process with the only type of translation they were familiar with, viz. non computer-assisted translation. The studies focusing on pure cognitive aspects of TM-assisted translation processes apply experimental research designs and deal with the cognitive effort of different TM match types (2) and cognitive usage/usefulness of the concordance feature (5). Hence, all studies were carried out as experiments.

In order to investigate the overall aims of the respective studies, the studies have applied three of the four categories of methods mentioned by Krings: product analysis, offline verbal-report data, and observation methods. Product analysis was used as a data collecting instrument in two of the studies investigating TMs' impact on translation products. Dragsted (1) analysed how target texts' sentence structure is affected by the implementation of a TM. O'Brien et al. (5) investigated the qualitative impact of translating with the concordance feature enabled/disabled. As for the methods and tools for observation, Dragsted (1) registered subjects' processing time using keystroke logging (Translog) in the non-TM experiment. Because it turned out that it was not feasible to integrate Translog with the TM system used (Trados), the subjects in her TM experiment were asked to indicate verbally when they had finished the text production phase. To investigate how translators segment texts when no TM is used, she defined translators' internal pauses by means of the length of translators' typing pauses using keystroke logging data. To measure cognitive effort, O'Brien (2) analysed processing speed and pupil dilation in connection with various TM match types using screen capture and eye tracking respectively. Aiming at investigating translators' types of pauses and support, Alves and Liparini Campos (3) applied keystroke logging (Translog) only to register translators' pausing during translation without a TM. In the experiments including a TM, the translation processes were recorded with screen capture software. To register room activity, Christensen and Schjoldager (4) used observation protocols. To investigate cognitive usage/usefulness of the concordance feature, O'Brien et al. (5) used eye tracking. Hence, observation methods have been applied in order to obtain empirical knowledge about the following cognitive aspects: time task length (1), segmentation (1), cognitive effort (2), types of pauses/support used (3), room activity (4), and cognitive usage (5). As regards offline verbal-report methods, Dragsted (1) and Christensen and Schjoldager (4) made subjects reflect on their cognitive processing by means of

immediate metacognition. O'Brien (2) asked her subjects to rate the editing effort of different matches using a questionnaire. O'Brien et al. (5) interviewed the subjects about how they assessed the usefulness of certain TM features. Alves and Liparini Campos (3) asked their subjects to produce media-based retrospective comments about types of support used. Based on the above observations, all studies can be said to triangulate methods. This means that in all studies the interpretation of the overall results is based on different forms of data, i.e. by means of data obtained by a concurrent mix of methods (Creswell 2009; see also Alves 2003). The analysis has shown that all studies combine data obtained by two or even three of the categories of methods mentioned by Krings (2005). Except from Dragsted (1), furthermore all studies combine offline and online methods, which might make the findings of the studies more reliable. The only methods which have not been applied in mental TM research studies so far are TAPs, dialogue protocols, video recording and brain pattern measurement. Obviously, dialogue protocols are only marginally appropriate for investigating TM translation because a TM is generally applied by individual translators remotely, even when they collaborate on the same translation project applying the web-interactive mode. TAP was actually considered by Dragsted (2004: 128), but based on the assumption that the verbalisation act slows down the mental processes and therefore the typing process used as indicator of subjects' pausing in her study, she decided not to apply TAP. In my view, studies which are focusing solely on metacognition (level-3 verbalisations) may obtain useful data with the help of TAPs, because in this case the interference with the cognitive processes would be of secondary importance. A tool which may be used with minimal risk of interference is video recording. Video recording can register room activity, the translator's behavior and facial expressions, the translator's desk and translator's interaction with other people and tools, i.e. various external processes. As regards brain pattern measurement, I assume that this might be a reliable tool in studies investigating cognitive effort, for instance because it provides information about the degree of activation of the brain. However, the tool suffers from the limitation that the brain activation registered during TM-assisted translation also reflects the cognitive effort needed for carrying out other actions, for instance typing the target text.

Notably, the review reveals that studies aiming at comparing TM translation with human translation obviously face methodological and practical difficulties. In fact, it seems as if some of the studies are methodology-driven rather than question-driven. This is indicated by the fact, that none of the studies apply more than one observation tool in the experiments where translators are supposed to use a TM. Dragsted (1) found that Translog was not feasible with the TM suite used (Trados) and, therefore, she used no observation tool in the TM experiment. Based on this, Alves and Liparini Campos (3) chose only to apply keystroke logging in the experiments where subjects translated without a TM. In their experiments including a TM, the translation processes where recorded by means of screen capture. Due to this, the experiments did not generate directly comparable data. What is more, Alves and Liparini Campos had to

supplement the data obtained by these tools with data collected by other methods in order to be able to investigate what type of support the subjects were using. The argument being that keystroke logging registers pauses, but does not unveil what sources of support are being used. Screen capture, on the other hand, registers which online tools are used as sources of support, but does not give access to pause data or information about which external sources of support have been used. Hence, neither screen capture nor keystroke logging can reveal anything about peripheral activities. In effect, in the experiments not including a TM the classification of types of support used was based on observation protocols and subjects' retrospective protocols exclusively. In the experiments including a TM, types of support used were classified by combining screen capture data with data from observation protocols and retrospective protocols. In my view it would have been very relevant to investigate not only which types of support translators use, but also which particular sources of documentation translators use and how. However, none of the tools applied in the study allow for such qualitative investigation. Interestingly, Torres-Hostench et al. (2010) use keystroke logging (InputLog) to investigate TM translation (Workbench by SDL Trados and TagEditor by SDL Trados 2007). They report no compatibility problems between InputLog and the Workbench. Problems are, however, reported when InputLog is used in combination with TagEditor. The main difference between the Workbench and TagEditor is that the former applies a so-called hybrid translation environment, whereas the latter applies a so-called side-by-side environment. In hybrid translation environments texts are translated in Word. In side-by-side environments, translation is carried out within the TM editor itself; here translators do not see the original format of the source text, but only a plain text displayed sentence by sentence with no pictures or background colors.

It is worth noting that all studies reviewed in this article are based on older versions of Trados (Workbench) applying hybrid translation environments, whereas most TM suites on the market, e.g. Déjà Vu, Star Transit and the latest version of Trados (SDL Trados Studio 2011), apply side-by-side environments. In effect, the findings of the studies might not be valid for TM translation in general. Most interestingly, Torres-Hostench et al. (2010: 267) found that translators are, for instance, less inclined to produce explicitations when they use a hybrid translation environment than a side-by-side environment. If we assume that this means that hybrid translation environments generally interfere with the translation process to a greater extent than side-by-side environments, this might indicate that the findings of the studies reviewed here might not hold good if they were to be replicated in side-by-side-based TM suites. Therefore, more research on side-by-side TM suites should be particularly encouraged.

What we know by now about TM translation as a mental activity carried out in a hybrid translation environment can be summarized as follows: Dragsted (1) found that translators when using a TM are forced to work with cognitive units by means of sentences which do not correspond with translators' natural segmentation units (phrases or clauses), that translators are less inclined to change the sentence structure when they translate with the help of a TM, that professional translators consider the

focus on sentences to be a disadvantage, whereas non-professionals consider it an advantage, and that the use of a TM reduces the time spent on end-revision. O'Brien (2) found that translators' cognitive load increases as fuzzy match values decrease, even though the relationship is not fully straightforward. Alves and Liparini Campos (3) found that when a TM is used the number of orientation pauses increases and during these pauses translators mainly use TM proposals as internal stimulus. Christensen and Schjoldager (4) found that students facing TM technology for the first time consider it a useful but at the same time deceptive tool affecting the translation process. O'Brien et al. (5) found that translators seem to be more inclined to use the sub-segment matches, for which they must initiate a manual search, than TM matches, which are retrieved automatically. They also found that translation quality increases with the use of the concordance feature, which might compensate for the fact that the qualitative gain goes hand in hand with an increased production time. Arguably, if increased production time is considered a consequence of increased cognitive load, it seems reasonable to believe that the use of the newest TM suites will make TM translation even more demanding. The argument being that they include an increased number of pop-up features such as AutoSuggest, which might distract translators cognitively.

The findings of the analysed TM studies indicate that without any doubt TM tools impact on translators' mental processes. Still, empirically documented knowledge about the nature of the mental processes taking place during TM-assisted translation is scarce. Therefore, more descriptive research is needed to understand how translators interact with TM tools and how these artifacts constrain the mental processes. In particular research on the mental consequences of the latest developments within TM technology seems desirable, for instance the integration of MT into the TM-assisted translation process and the adoption of side-by-side environments. Also, studies which combine the investigation of what happens in the individual translator's mind (internal processes) with what happens in the translator's environment (external processes) are needed in order to learn more about situated and distributed translation and the increasingly relevant role played by tools and teams. Arguably, the fact that translation in real-life-translation, as a rule, is now carried out as a shared activity can be said to widen the concept of translation processes to embody a variety of different workflows and related mental processes, which to my knowledge have not been dealt with in translation process research so far. As regards a theoretical frame for future TM research, the paradigm of situated, embodied cognition seems highly useful, because it takes into account the fact that translation as a distributed activity does not take place only within the brain of an individual human.

Research on external processes within which the internal processes take place could be taken further in a number of ways. Among other things, it might be relevant to investigate how the sharing of TMs takes place and which mental processes are initiated by the fact that translators using a shared TM in fact to a large extent are no longer translating, but revising texts generated by others. In order to fully understand how a TM constitutes shared knowledge, studies focusing on secondary processes like

maintenance of TMs are also needed. Here, combining cognitive research with ethnographic research intended to reveal work communities' common understanding of this phenomenon seems desirable. As all studies carried out so far are experimental studies, furthermore field-studies by means of studies which investigate translation processes of professional translators working in their usual work environment (see Perrin 2006) should be encouraged. As pointed out by Göpferich (2008: 16), it might, however, be difficult to conduct field studies. She argues that even if we study translators who work in their usual translation environment, we create non-ecological situations. What is more, in a workplace study the researcher is unable to control as many variables as can be controlled in an experimental setting. Hence this kind of research is delimited in its validity as is the experimental research reviewed in this article, but in a different way. A suitable solution might be to conduct experimental field-studies which adopt a combined approach to internal and external processes. This would allow us to opt for a high degree of ecological validity and to control relevant variables. Probably, the challenge will be to convince translators and agencies that they need to participate in translation research in order to be able to profit from it. I suggest that we start off by telling them that translation tools control their translation processes and products, and not only in a positive way.

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