Chapter 2. A mapping exercise: Eye tracking and translation

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Abstract. This chapter focuses on the most prolific period of eye-tracking research in Translation Studies considered against the broad backdrop of the four eras of eye-tracking-based research in other disciplines that have used eye-tracking experiments for several decades. Subdivided into two sections, the chapter offers a contextualisation of eye tracking whilst first asserting the widely accepted relationship between visual attention and cognitive effort. By mapping out this emergent niche in Translation Studies, observations on the diachronic developments and the synchronic demands of eye-tracking research in Translation Studies are brought to the attention of the readers. In its desire to contextualise the field, the chapter raises critical questions regarding current methodologies and data analysis in Translation Studies research within this niche and correlated experiment-based approaches. The chapter goes on in the second part to discuss future developments in the field with opportunities to triangulate eye-tracking data in multi-sensorial experiments, by adopting additional complex tools to measure other physiological responses, as part of a broader encapsulation of the body-mind relationship into our conceptualisations of cognitive effort. In its final remarks, the chapter looks at a broader reconceptualisation of the discipline in relation to the growing cross-disciplinary demands of any

holistic experimental approach to evidence-based studies of translation phenomena.

1. Introduction

In her chapter entitled "Cognitive Effort in Translation, Editing, and Post-editing", Isabel Lacruz maps the last decade of developments in eye-tracking-based research in Translation Studies – henceforth TS (2017:11-12). She observes that "since 2010, eye-tracking methodologies have become central to the understanding of cognitive effort in translation, and especially in post-editing [and] are routinely used to inform the dialog between machine translation developers and human users of the technology" (2017:390). We share her view and want to add some observations based on the correlated methodologies that surround eye-tracking based methods, whilst also focusing on some of the diachronic and synchronic challenges that come from investigating translatorial activities against the complexity of the human mind. Firstly, this chapter proposes some considerations on the relationship between eye-tracking research more widely and the methodological innovation that it has brought to the analysis of translator effort. Secondly, it moves to observations that link eye-tracking based studies to multifaceted researcher skillsets. Thirdly, it reflects on the stimulating obstacles to further development of these empirical methodologies and a reassessment of the body-mind relationship as biologically driven by the brain systems that simultaneously process mental and motor data. In this perspective, the chapter also ponders some of the questions that readers will find answered by the following contributions to this volume. The concluding remarks focus on broader academic and research questions that we hope will encourage readers to consider the best ways forward to advance experimental cognitive research projects using eye-tracking technologies to study the processes, people, actions, and events that define translation activities.

2. The road so far

First and foremost, we acknowledge two important milestones. The first is discipline-specific: recognising, as Ferreira and Schwieter suggest (2017:3), that "the integration of cognitive science into translation and interpreting studies […] has formed an interdisciplinary-rich field", which most researchers describe as translation process research (TPR). In this volume, however, the readers will find that some of the research presented has ambitions to test hypotheses in product- or reception-oriented studies, by engaging with audience responses to the translated materials, rather than focusing only on the process.

The second milestone is technological and methodological. New approaches have emerged at an ever-increasing pace, pushing the threshold of complexity in eye-tracking research ever higher year after year. This consideration induces us to reflect more broadly on the specificity of this research method, which is the predominant focus of the chapters collected in this volume: eye-tracking data collection. Almost twenty years ago, in 1998, Keith Rayner – one of the most famous and pioneering researchers in eye-tracking research – published an article entitled “Eye-tracking in Reading and Information Processing: 20 Years of Research” (1998). This seminal piece provided a far-reaching and in-depth review of studies on eye movements during diverse tasks ranging from reading and typing to scene perception and visual search, and covered topics such as the physiology and characteristics of eye movements, the perceptual span, and information assimilation. This article spans 32 pages and is followed by 18 pages with a staggering 803 references.

Rayner’s 1998 article was published at the cusp of what he later dubbed the “fourth era” of eye-tracking research, in which he saw the task of researchers as being validating or disproving models of reading and information processing (2009). His 20-year review (1998) focused on research in the “third era” of eye-tracking research, the advent of which he announced in a paper published twenty years earlier (Rayner 1978). The third era saw a flourishing of research paradigms in line with advances in eye-tracking and computer technology, which in turn contributed to vast improvements in the ecological validity of experiment designs and faster and more detailed analysis of enhanced eye-tracking data. One of the most notable and earliest contributions to eye-tracking research in the third era was Marcel Just and Patricia Carpenter's paper "A Theory of Reading: From Eye Fixations to Comprehension" (1980), which, for better or worse, still informs a large amount of eye-tracking research in TS to this day. Their theory of reading was based on two key assumptions. The first – the immediacy assumption – presupposes that a reader will attempt to process each word of a text or other stimulus as it is encountered, even at the risk of making an incorrect judgement. The second – the eye-mind assumption – posits that the amount of time that the eyes remains fixated on a stimulus is directly proportionate to the time taken to process it. In summary: "there is no appreciable lag between what is being fixated and what is being processed" (Just and Carpenter 1980:331). This model therefore established a direct link between the duration of fixations and cognitive effort – for a discussion of the latter, see Section 3 below. Jakobsen (2017:33-34) recently offered a critical review of this hypothesis, referring to investigations that focused on reading for comprehension rather than reading for translating – which refer back to work carried out in the mid-2000s (see Jakobsen and Jensen 2008). Such eye-tracking research on reading became an inspiration for Translation Studies scholars, who had to consider the substantial physical difference of reading for translating, which includes always a form of parallel reading, mixed with typing:

> Reading while typing a translation involves constant shifts of visual attention from ST reading in one window to reading TT and monitoring the typing of new text in another and back to reading at the approximate location in the ST that was being read a moment earlier. (Jakobsen 2017:34)

It took some time before the intuition of this added complexity led to consideration of the complexities of the neuromotor systems in the brain that are engaged by these parallel actions. The advances in neuroscience of the last ten years have also greatly enhanced the knowledge of the brain's circuitry more widely, at times forcing a reconceptualization of the perhaps simplistic method of a modular system and engaging ever more with the complexity of cognitive faculties as affected by movement, emotion, context, social interactions, and so on (Di Paolo and De Jaegher 2012; Dickerson, Gerhardstein, and Moser 2017; Pulvermüller, Shtyrov, and Ilmoniemi 2005). As a point of departure, the eye-mind model, while possibly rather basic, still holds true and shares some common ground with many more comprehensive models of reading (for example, E-Z Reader, which is now in its tenth iteration: Reichle, Warren, and McConnell 2009).

Many researchers would however argue that the eye-mind hypothesis is an over-simplification of a much more complex process (see, for example: Anderson, Bothell, and Douglass 2004; Murray, Fischer, and Tatler 2013; Reichle and Reingold 2013). Even remaining within the restricted perspective of observing only reading/writing as cognitive, and not neuromotor, activities, this model does not, for example, properly account for all of the complexities of lexical and linguistic (see Juhasz and Pollatsek 2011; Rayner and Liversedge 2011), syntactic (see Clifton Jr. and Staub 2011), or parafoveal-on-foveal influences (see Hyönä 2011; Drieghe 2011) in the reading process, and is easily challenged by parallel graded attention models (see Engbert and Kliegl 2011), an alternative model to so-called serial processing models.

The fact that some researchers in Translation Studies may prefer to continue to adopt Just and Carpenter's theoretical framework does not in any way diminish the validity of their research; rather, it reflects a number of problems inherent in translation studies more broadly as a discipline (see also Lacruz 2017). TS is fundamentally interdisciplinary in nature and frequently "borrows" models, methods, and concepts from adjacent and more distant disciplines (the very concept of "borrower" is vividly discussed in O'Brien 2015). While TS scholars are continually looking to extend the boundaries of their discipline in this way, this venture inevitably entails a certain amount of apprehension when dealing with concepts so different to those at the core of the discipline. It may be argued that such apprehension manifests itself by the choice of simpler models. In many cases this issue boils down to problems of self-assurance and presence in a new field, which in turn leads to another all-too-frequent shortcoming in TS: the lack (or inadequacy) of proper interdisciplinary collaborative teams. That said, the academic context and methodological approaches are finally starting to undergo a period of rapid change and there is evidence emerging of large projects focusing on scaling up the analysis of new and 'historical' data collections (see, for instance, Carl, Bangalore, and Schaeffer 2016).

It might come as a surprise to some that the first venture into the eye-tracking paradigm in Translation Studies proper was only just over ten years ago, with Sharon O'Brien's paper on using eye tracking to examine how translators interact with translation memory matches (O'Brien 2006). One paper published over a decade earlier (Hyönä, Tommola, and Alaja 1995) employed eye tracking to study processing load in simultaneous interpreting, but this research was firmly rooted in cognitive psychology and paid no attention to translation (or interpreting) theory or the challenges or problems concomitant with any act of translation. Despite the youth of this paradigm within TS (Doherty's chapter provides an admirably succinct literature review of some of the main uses of eye tracking in TS), the applications of eye tracking in this field have grown exponentially over the past decade, primarily along three separate (but interrelated) pathways. The first of these pathways concerns the methodological challenges and solutions posed by the use of eye tracking in TS research; such studies tend to focus on matters such as experimental design (for example, O'Brien 2009) and data analysis (for example, Hvelplund 2014). The second, and perhaps most populous, in terms of the amount of research conducted in this subfield, can be broadly categorised as process-related research, examining the working processes and practices of practicing translators (for example, Jensen 2011) and translators in training (for example, Sharmin et al. 2008) and the use of computer-aided translation software (for example, O'Brien 2008), among numerous other subjects in translation process research. The final area can be described as product and reception studies remains a fairly pristine and unexplored area of interest (Lacruz 2017; Shreve and Lacruz 2017) and looks at how translation products are received or evaluated by their audience, in particular with respect to machine translation quality assessment (for example, Doherty, O'Brien, and Carl 2010) and audiovisual translation reception (for example, Kruger 2016). There have also been a very limited number of studies on text-based reception (Kruger 2013; Maksymski et al. 2015) – this area has arguably been subject to the least attention in TS. Needless to say, these three areas are all interrelated; they frequently borrow methodological elements from one another in the design of their experimental protocols. It is impossible, for example, to study translation reception or the translation process (which are, arguably, the ‘applied’ aspects of eye-tracking research) without the fundamental methodological aspects covered in the first pathway (the ‘pure’ theoretical aspects): repeatability of results and scrutiny of methods is essential in any empirical discipline.

It goes beyond the scope of this chapter to provide a summary of current models and methods in eye-tracking research beyond Translation Studies, notably because the resources are already plentiful and more than adequate in this regard (see Duchowski 2007; Liversedge, Gilchrist, and Everling 2011; Holmqvist et al. 2011 for three excellent primers in eye-tracking research). However, the methodological aspects of experiment design covered in these works, in addition to the wealth of other available resources, are but one side of the empirical coin. In conjunction with the experimental aspect of eye-tracking research, TS researchers also need to update their analytical toolkit. Quantitative analysis of data has, comparatively speaking, been used far less in TS than the more traditional qualitative methods of analysis. This deficiency in quantitative data analysis methods in TS, something that Doherty’s chapter looks to address, has only recently started to be tackled, with the publication of works such as Mellinger and Hanson’s superb *Quantitative Research Methods in Translation and Interpreting Studies* (2016). Despite this, when analysing differences between datasets, there is still an over-reliance on comparisons of descriptive statistics – means, medians, standard deviations, etc. – and, for those venturing beyond more basic comparisons, on null-hypothesis significance testing (NHST) yielding *p*-values from *t*-tests and analyses of variance (ANOVAs). Again, like in the experimental domain itself, Translation Studies has, on the whole (there are of course exceptions), not kept abreast of developments in inferential statistics. There has been a tendency to move away from *p*-values, which have been subject to severe criticism since the 1950s (Cohen 1994), not least because they are so frequently misinterpreted (see Greenland et al. 2016). Indeed "even a correct interpretation of *p*-values does not achieve very much" (Cohen 1994:1001). The future – for Translation Studies at least – lies, first, in better visualisation of data (it has been common practice in psychology and other fields for decades; something John Tukey advocated as early as 1977), second, in the routine reporting of effect sizes with confidence intervals when comparing datasets, and third, making better use of robust statistical methods such as linear regression, correlation tests, and mixed-effects models to examine the various relationships in eye-tracking data (see Mellinger and Hanson 2016 for excellent introductions to all of these points and more).

Thus, not only does Translation Studies need to update its experimental and theoretical toolkit using the models developed in fields such as cognitive psychology (see, for example, the discussion on the dual- and triple-task paradigm in Section 3 below), but also it needs to advance its methods of statistical analysis and presentation to take account of developments in statistics which have been prevalent for decades and are no longer "desirable", but are in fact becoming increasingly "mandatory" to achieve proper recognition for analysis of experimental results:

> Good statistical practice, as an essential component of good scientific practice, emphasizes principles of good study design and conduct, a variety of numerical and graphical summaries of data, understanding of the phenomenon under study, interpretation of results in context, complete reporting and proper logical and quantitative understanding of what data summaries mean. No single index should substitute for scientific reasoning. (Wasserstein and Lazar 2016:132)

We are, in effect, being pulled in two directions towards two distinct fields – cognitive psychology, or even cognitive sciences more broadly, and mathematics – which are, to many in TS and related disciplines, quite alien and daunting. This situation also suggests that more courses on research methodologies and data analysis (quantitative methods, in particular) should be introduced for TS students (this observation focuses on some skills and learning perspectives that may need wider debate at pedagogical and institutional level, as suggested in the broader discussion below). However, any disquiet that we may feel when venturing into pastures new cannot serve as an excuse for ignoring decades worth of research in these already established fields. It was in 1978 that Rayner announced the dawn of the “third era” of eye-tracking research, stating that the success of this era would be contingent on the researchers in designing engaging and informative studies (Rayner 1978:652). If we compare the state of the art in Translation Studies with that of cognitive psychology, in terms of the complexity of the theoretical models being employed and developed, we appear to be lagging behind somewhat. While we may be using fourth-era technology like our colleagues in psychology, our methodological perspective is still, for the most part, rooted in third-era principles.

If we consider the history of eye-tracking research in natural reading research and cognitive psychology, the problem facing Translation Studies becomes clear. Rayner’s *20 years of research* was published nearly 20 years ago (1998), and that paper reviewed the *previous* 20 years of research (from 1968 onwards). These *20 years of research* covered Rayner’s so-called “third era” of eye-tracking research, which began in the 1970s. Before the third era, the second era (1940s-1970s) saw studies by the likes of Buswell (1935) and Tinker (1946). Before that, the first era began with Javal’s (or more accurately, Lamare's: see Wade and Tatler 2009) famed works at the end of the 19th and start of the 20th century (Javal 1878, 1879, 1905). There are even valid claims to eye-tracking research (in primitive forms) as far back as Aristotle (see Wade and Tatler 2011). Translation Studies, as a discipline, has some catching up to do.

3. The road ahead

Lacruz reminds (2017:387) us that "to distinguish between different levels of cognitive effort, it is first necessary to define cognitive effort in a way that is amenable to empirical investigation". The definition of cognitive effort comes from a range of disciplines and is also a concept with an immediate, intuitive dimension. However, its use may have been taken for granted in some research adopting eye-tracking methods. In other words, eye-tracking research in TS has achieved most of its research results by adopting one of the possible definitions of *cognitive effort*. In cognitive sciences, the term tends to be defined and refined for each occurrence. In one of the first recorded uses and definitions of the collocation *cognitive load*, Pas (1992:429) explains:

> *Cognitive load* is a multidimensional concept in which two components – mental load and mental effort – can be distinguished. *Mental load* is imposed by instructional parameters (e.g., task

> structure, sequence of information), and *mental effort* refers to the amount of capacity that is allocated to the instructional demands.

This definition, integrating efforts and processing, was later revised in Paas and Van Merriënboer (1993), as they proposed measuring the relationship between tasks and their impact on mental faculties. Their concept of "mental effort", however, represents a slightly different conceptualization of cognitive effort:

> [mental effort] may be defined as the total amount of controlled cognitive processing in which a subject is engaged. Measures of mental effort can provide information on the cognitive costs of learning, performance, or both. (Paas and Van Merriënboer 1993:738)

Whether the brain circuitry separates the two processes may be debatable (see discussion below). Over the last three decades, "mental effort" seems to have been more popular in educational research, whilst in neuroscience – including studies in applied neurolinguistics – the predominant term seems to be "cognitive effort". Lacruz (2017:387-388) discusses the initial conceptualization of the dual-task in relation to cognitive effort to brain's memory usage (Tyler, Hertel, and McCallum 1979); she then goes on to explore how the triple-task model that created experiments on writing

(Kellogg 1988) has been less explored than it might have possibly been expected. Lacruz's insightful summary of these early studies in cognitive efforts leads her to notice how

> Curiously, the dual-task and triple-task paradigms do not appear to have been used to investigate cognitive effort in translation, revision of translations, or post-editing of machine translations. Nevertheless, there are hints in the monolingual research […] that these should be useful techniques for translation process research. (Lacruz 2017:388)

It is also very curious that the chosen definition of cognitive effort that has exercised the most prominent influence on TS work in eye-tracking is linked to memory efforts in processing the input data streams in the brain. "Cognitive effort refers to the mental effort involved in reading the texts, thinking about how to translate and how to correct mistranslations, selecting the desired product, and reflecting on the chosen solutions" (Lacruz 2017:387). Krings (2001) had also broken down the concept into three components: temporal, technical, and cognitive effort in relation to post-editing of machine translation outputs; the attempt of measuring these efforts (O'Brien 2005) later led to O'Brien's influential eye-tracking-based experiment (2006).

In cognitive science, brain studies are connecting both neuronal systems and analysis of biological reactions more widely. For instance, cognitive effort is maximised by the need to activate motor systems and reactions; therefore, in any of the dual- or triple-paradigms, and studies of cognitive effort in TS so far, the analysis of the impact of physical tasks (typing, becoming accustomed to different software packages, moving the mouse, adjusting on the chair, and so on) might have been underestimated. When using existing data collected in experiments and when triangulating data, considering the neuromotor dimension could already engender a revolution in our current conceptualizations of cognitive effort. In the brain, neuronal connections are being described more and more as nodular (and not modular) interlocking systems that make up the networks that coordinate the brain's functions.

"The usual interpretation is that participants exert more effort when confronted with higher demands, resulting in more task-specific activation [of the brain systems]" (Schmidt et al. 2012:1). These higher demands are also driven by the neuromotor systems and by physical factors, as documented in studies considering the ergonomic dimension of the translation process (Ehrensberger-Dow 2017). In neuroscience, due to this shift from the modular to the nodular perspective, the question of 'how the brain works' looks at a multitude of internal and external stimuli that have a cognitive impact on the computational processes inside the brain. Diverse and fascinatingly complex conceptualizations are collated in a Special Issue of *Neuron* (2017). There, a range of hypotheses in need of further testing is presented and postulated; one common denominator seems to emerge: the modular notion of the brain system needs to give way to 4-dimensional theories, which include response times, as well as the spatial dimension of the interrelations between the brain circuitry.

Two such postulations deserve more space in this discussion. One theory includes studies on the brain's computational activities whilst also considering its responses to emotional and social contexts (Hari 2017). An alternatively and equally powerful theory depicts the composite back-forward computational processing of information that could prove to be an ideal framework to look at the multi-task events that are "intrinsically ignited" (Deco and Kringelbach 2017:961-62), as happens in the cognitive processes activated by translation work. Translation events in the brain result from recurrent feedback and feedforward dynamics. Such recurrent events can be recorded in the brain when studying translational acts by considering pauses (O'Brien 2006) as well as differences in peaks of activity, in a status of normal activity, or idle moments as part of this dynamic conceptualization of the workings of the brain (Deco, Jirsa, and McIntosh 2011), as discussed below.

Hari (2017) puts forward a particularly strong, evidence-driven hypothesis, which includes experimental approaches to consider the "interaction-driven" cognitive functions of the brain. She suggests that the brain not only works in a response mode, but rather "the brains (and their owners) are interactive, not only reactive, although often studied in unidirectional stimulus – response setups" (Hari 2017:1034). Hari's work is particularly significant in a perspective that joins up enactivism (Di Paolo and De Jaegher 2012) and cognitive functions: "We have argued earlier that social interaction, as such, is central for the whole human brain function" (Hari et al., 2015; Hari and Kujala, 2009). Aligned with these positions embracing the polymorphic complexity of the brain systems in her work on translation and cognition is O'Brien (2015; 2017). In particular, what O'Brien (2017) attributes to cognitive effort in her discussion of the evaluation of cognitive processes involved in post-editing of machine translation could, arguably, be applicable more broadly to any experiment invested in ascertaining computational cognitive processes. Specifically, she (2017:325) observes that "the socio-cognitive aspects are intertwined and the situative, textual, and organizational factors could all impact the PE process at a cognitive level". In their attempt to answer how the brain works, Pillai and Jirsa (2017:1010) open by stating that "the question ultimately translates into the study of the principles underlying the relation between behavior and brain dynamics". The current emphasis in neuroscience on experiments, theories, and visions to understand the computational processes of the brain is no longer separated from the situational and emotional, the social interactive dimensions. In a way, this holistic approach could be seen as marrying the stimulating ethnographic direction of research in translation process research (see overview of the current state of play in Jakobsen 2017:39; and Hubscher-Davidson 2015; Hubscher-Davidson 2016) and eye-tracking or even novel biometric methods for hard data collection. After all, they all point in the direction of considering recent studies in neurocognitive sciences and their integration of measurements and study of biological components in analysing the brain's cognitive reactions to stimuli.

Let us now look at the second, stimulating postulation according to which the brain dynamics are both interactive and reactive. Complex interrelations across the various data streams that the brain processes simultaneously at any given time "make the brain a complex, non-linear dynamical system" according to Deco and Kringelbach (2017:961; see also Deco, Jirsa, and McIntosh 2011). In this dynamic system, a single concept of cognitive effort seems to be limiting. Or better, cognitive effort cannot be isolated from the other contrasting and simultaneous efforts of the brain to make sense of the correlation of inputs constantly engaging its computational and processing systems. To expand on Deco and Kringelbach's work, they suggest a conceptual framework to study the ways in which information propagates in the brain as "intrinsic ignition" which they explain in these terms:

> Informally, the concept of intrinsic ignition refers to the capability of a given local node (single neuron or brain area) in space to propagate feedforward and recurrent neuronal activity to other nodes in the network as measured by the whole-brain integration elicited. (2017:961)

Were we to scrutinize considerations on cognitive efforts in line with this paradigm, it would be possible to identify *events* that correlate *one* stimulus to a set of cognitive reactions – which continues to be extremely arduous to achieve in experimental conditions. This approach could significantly enhance our understanding of translation processes as events in a continuum of brain activities that can and should be considered simultaneously, including the neuromotor elements, and it would enable us to look at the "event-related potential" (ERP) of emotive stimuli, together with hard stimuli (recent ERP-based studies show promising results on identifying processing of single events Nieuwland 2015; Chwilla, Virgillito, and Vissers 2011; Padovani et al. 2011). With neuroscientists moving towards all-encompassing experimental and theoretical positions, where situational, emotional, cognitive stimuli are equally and simultaneously considered (with many differences in depth and reach), the individual events that can be studied in controlled conditions are becoming more and more complex. It is fair to predict that it will become possible to design experiments that replicate many of the 'natural' conditions of translation production or reception. The risk of a schism along a qualitative and quantitative divide in cognitive translation research (probably only a rhetorically provocative argument evoked in Muñoz Martín 2017) does not need to be a deterministic given, and Translation Studies would seem to go in the opposite direction taken by most other disciplines.

Even if we were to stay closer to the eye-mind theory, there are important links between eye and neuromotor systems that seem to have been underestimated so far. For instance, only neuroscientific discoveries regarding vision, perception, and sight would be enough to revolutionize translation studies' approach to experiments assessing the cognitive efforts in translating, post-editing, and similar mono- or bilingual tasks that involve the neuromotor systems. In fact, "[visual scientists now] argue that what we see is also shaped by what we *know* about the world: in other words that learning, memory, and expectations play a crucial role in molding our perceptions" (Goodale and Milner 2013:11-12). In their absorbing *Sight Unseen: An Exploration of Conscious and Unconscious Vision* (2013), Goodale and Milner report their discoveries regarding the complexity of processing data streams relating to vision (alone!) and regarding the receptor systems that control the processing of input information from our sight. Vision is both conscious and unconscious and its complex relationship with seeing within the context of a 3D space, where we use sight to perceive, touch, and interact with 'objects', is determined by the ways in which the circuitry of the brain processes data via two streams:

> the ventral perception stream and the dorsal action stream are two independent visual systems within the primate cerebral cortex. Nevertheless, the two evolved together and play complementary roles in the control of behaviour. In some ways, the limitations of one system are the strengths of the other. The ventral stream delivers a rich and detailed representation of the world, but throws away the detailed metrics of the scene with respect to the observer. In contrast, the dorsal stream delivers accurate metrical information about an object in the required egocentric coordinates for action, but these computations are fleeting and are for the most part limited to the particular goal object that has been selected. (Goodale and Milner 2013:173)

In other words, for the purposes of research with neurocognitive ambitions in TS, novel re-definitions of sight and vision could be considered to further advance research that involves using eye trackers as one tool among many to collect and analyse data.

The above incursion into complex and current theories of the workings of the brain – alas, very simplistically presented here – is only illustrative of one fundamental priority for researchers in TS (were they to define themselves in cognitive translation studies or translation process research): extensive and cross-disciplinary collaborations are the only way forward. From Jakobsen's earlier eureka moments onwards (Jakobsen 1998, 1999, 2002), many eye-tracking data collections have involved triangulation in the data analysis; the datasets that would be triangulated against eye movements would often include neuromotor-driven actions – keylogging, observation of mouse paths on the screen, and so on. Had they even involved triangulation with verbalisations (Muñoz Martín 2017:555 reminds readers of the quantitative vs qualitative divide), the observations of the working of our two-fold sight could lead TS scholars to significant reinterpretations of previous findings in our discipline. Furthermore, in experiments considering processes of translation, revision, post-editing that involve neuromotor as well as mnemonic activities, actions driven by the brain motor system are not necessarily in linear, proportional relationship with eye movements.

In future, collaborative research, the foci of our interest in the methods to better understand both the comprehension and production processes of translation thus need to be multiple. Eye-tracking data will be analysed in relation to other biometric parameters. By integrating and analysing data that combine input streams from eye tracking – emotion recognition, electro-encephalogram (EEG), galvanic skin response (GSR), and electrocardiograph (ECG), among others – using non-invasive sensors, TS scholars could be able to contribute to enhancing the broader understanding of the interactions that make up *cognitive effort*. Each one of these methods are used for measuring emotional response and cognitive effort – for example, the galvanic skin response sensor collects data on changes in body temperature and sweat as emotive responses. These methods can elicit further questions on the decision-making process which, in translation (far more than in writing tasks), also necessitates activation of the motor system, as well as on the link between readability and end-user responses to translations (reception in audiovisual and other types of translations, including fiction – see Filizzola's, Walker's and Łabendowicz's contributions to this volume; see also Romero-Fresco 2018). In a pro-active and forward-looking view of the discipline, we could be excused the ambition to argue that TS scholars have a privileged position, as translation work inevitably involves multiple concurrent activities, which challenge the ignition of neural concatenated reactions. The understanding stemming from translation scholars' work on discourse, competences, cognition, processing theories and a plethora of other cross-disciplinary approaches could, in future developments of the discipline, make substantial contributions to developing the very cognitive paradigm itself, rather than only borrowing from it.

Each of the data streams discussed above can be analysed from a visual as well as a computational perspective where the data from each sensor are layered on top of each other, thus enabling to recognize potential peaks of cognitive effort as emerging from the different data streams. Alternatively, individual or interpolated data streams can be assessed, compared, and contrasted in an integrated data analysis. This new typology of biometric experiments would make it possible to look at more complex data – without considering even more refined yet expensive neuroimaging procedures – by adopting methods that focus on the analysis of EEG data to take an event-related potential (EPR) approach (Nieuwland 2015; Chwilla, Virgillito, and Vissers 2011; Padovani et al. 2011).

By integrating multiple sensors and data sources, new biometric experiments would respond to suggestions that “recent development is moving the focus from single brain areas to dynamic networks whose nodes and connection strengths can change over time” (Hari and Parkkonen 2015:1). To achieve these integrations, eye-tracking based studies should increasingly look towards complex, collaborative teamwork to enable TS scholars to work on hypotheses that refer to the complexity of the brain beyond the eye-mind hypothesis. This need is becoming a priority in translation process research, as noted in Jakobsen’s recent remarks:

> TPR's assumption of a mind–brain–behavior/body correlation can assimilate psychological and socio-cognitive ideas such as [Chesterman's tongue-in-cheek statement that "translation is something that people do with words" (Chesterman 1989:6)] for reembedding and extending TPR. More attention will no doubt be paid in future to the roles of emotion, ergonomics, and the environment, and TPR is likely to further strengthen its association with social and cognitive psychology, as well as with neuroscience. (Jakobsen 2017:42)

It is no small feat. And assimilation may not necessarily be the best way forward, but rather collaboration to embed new and re-embed other disciplines in the study of processes. It is an exciting time to be carrying out eye-tracking research because mind-behaviour processes can be studied by novel methodologies following intuitions and hypotheses that were unthinkable only a decade ago.

Should we perhaps consider that the need for a leap forward is not so much ontological but institutional? The stimulating ethnographic, neuroscientific, and multimethod dimensions that TS scholars have long since embraced are better suited to research teams than individuals working in isolation, or pair collaborations. We could argue that the leap forward is more institutional and pragmatic. Translation Studies has become an area for extensive interdisciplinary research; are we sure that, institutionally, we should still sit (as it happens for many of our MA, MSc, and PhD programmes) within Faculties of Arts and Humanities, or of Modern Languages, or Linguistics, Philology, and so on? In the many international contexts in which it is not possible to have Faculties of Translation and Interpreting – which could already be an improvement, but not an institutional revolution – should we not strive academically to direct the discipline towards organizational units such as research centres, institutes, and similar cross-faculty and cross-discipline setups? Studies of the mind-body-behaviour relationship would achieve their best results and enhance their credibility by working across disciplines with colleagues in teams, including varying degrees of involvement with colleagues in STEM (science, technology, engineering and mathematics), Social Sciences, and Arts and Humanities. It will not be easy. It will however be highly rewarding. Cognitive science is moving in that direction and eye-tracking-based experiments are moving towards multiple inputs and scaling up. The time is ripe for reconsidering academic positioning and let the research questions and our curiosity in these areas take the wheel rather than letting our activities be driven by rusty, obsolete, and often restricting institutional setups.

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