

## **COGNITIVE EFFORT IN DIRECT AND INVERSE TRANSLATION PERFORMANCE: INSIGHT FROM EYE-TRACKING TECHNOLOGY**

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**Abstract:** This case study examined the translation performance of four professional translators with the aim of exploring the cognitive effort involved in direct and inverse translation. Four professional translators translated two comparable texts from English into Spanish and from Spanish into English. Eye-tracking technology was used to analyze the total time spent in each task, fixation time, and average fixation time. Fixation count in three areas of interest was measured including: source text, target text, and browser, used as an external support. Results suggested that although total time and fixation count were indicators of cognitive effort during the tasks, fixation count in the areas of interest data showed that more effort was directed toward the source text in both tasks. Overall, this study demonstrates that while more traditional measures for translation difficulty (e.g., total time) indicate more effort in the inverse translation task, eye-tracking data indicate that differences in the effort applied in both directions must be carefully analyzed, mostly regarding the areas of interest.

**Keywords:** Directionality in translation. Cognitive effort. Bilingual dominance

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## **ESFORÇO COGNITIVO NO DESEMPENHO EM TRADUÇÃO DIRETA E INVERSA: UMA PERCEPÇÃO A PARTIR DA TECNOLOGIA DE RASTREAMENTO OCULAR**

**Resumo:** O presente estudo de caso analisou o desempenho tradução de quatro tradutores profissionais com o objetivo de explorar o esforço cognitivo envolvido durante a tradução direta e a inversa. Quatro tradutores profissionais traduziram dois textos comparáveis do inglês para o espanhol e do espanhol para o inglês. A tecnologia de rastreamento ocular foi usada para analisar o tempo total gasto em cada tarefa, o tempo de fixação, e o tempo médio de fixação. A contagem de fixação em três áreas de interesse foi medida e inclui: a) o texto de partida, b) o texto de chegada e c) o navegador de internet, usado como apoio externo. Os resultados sugerem que, embora o tempo total e contagem de fixação sejam indicadores de esforço cognitivo durante as tarefas, os dados da contagem de fixação nas áreas de interesse mostram que mais esforço foi alocado ao texto de partida em ambas as tarefas. De maneira geral, este estudo demonstra que, enquanto as variáveis tradicionalmente usadas para aferir níveis de dificuldades durante uma tradução (e.g., o tempo total) indicam um maior esforço na tarefa de tradução inversa, os dados de rastreamento ocular sugerem que as diferenças no esforço aplicado em ambas as direções devem ser cuidadosamente analisadas, sobretudo em relação às áreas de interesse.

**Palavras-chave:** Direcionalidade em tradução. Esforço cognitivo. Domínio bilíngue.

### **1. Introduction**

Translation Studies (TS) is a relatively new area of research that builds on theories and methodologies from other fields, especially psycholinguistics, cognitive science, and expertise studies. At the same time, TS has been successful at adapting experimental designs that construct a unique tradition (Ferreira, Schwieter, and Gile 2015). Recently there has been a significant increase in the empirical work drawing on what exemplified in special issues of international journals (e.g., Ehrensberger-Dow, Englund Dimitrova, Hubscher-

Davidson, and Norberg 2013) and book volumes (e.g., Ferreira and Schwieter 2015; Schwieter and Ferreira 2014a; Shreve and Angelone 2010). Directionality in translation has offered important contributions in understanding the translation process and in studying how translation performance may be dependent on a variety of variables involved in the process (Buchweitz and Alves 2006; Ferreira and Schwieter 2017; Pavlović and Jensen 2009). Different levels of cognitive effort are applied depending on the task at hand (Ferreira 2014) and the amount of attention that is directed towards the source text (ST) and target text (TT) depends on how the translator understands and processes the task. We hope this analysis can contribute to the still incipient body of work on TPR that uses eye-tracking data, a rather complex field, not only because of the number of participants in this sort of experiment but also because eye fixations tend to vary among subjects.

## **2. Background**

### **2.1. Directionality in translation**

Despite the taboo against IT practice (Feltrin-Morris 2008), IT translation is performed on a regular basis by professionals and novices alike. Globalization in our modern world demands translators and interpreters (Ordoñez López, 2010), leading to more studies on translation processing and a better understanding of the intervention of translation and interpreting services, in both directions of translation. In this sense, directionality in translation has recently resulted in an increase in the number of studies that contribute to understanding the cognitive mechanisms that are involved in the translation process (e.g., Alves and Gonçalves 2013; Ferreira 2012, 2014; PACTE 2011; Pavlović and Jensen 2009). There remain several gaps in what we know about the practice of inverse translation (IT) in contrast to direct translation (DT) and as such, additional studies are necessary to make further advancements in TPR.

In a study investigating directionality in translation processes by means of eye tracking, Pavlović and Jensen (2009) looked at the effects of directionality on gaze time, average fixation duration, total task length, and pupil dilation, all of which were interpreted as indicators of cognitive effort. Students and professionals translated two comparable texts from Danish into English (DT) and from English into Danish (IT). The results showed that for both groups inverse translation tasks on average lasted longer than DT tasks. Furthermore, pupil dilation values, previously shown to be positively related to cognitive effort, were higher in the inverse tasks. In terms of average fixation duration, results showed that professional translators had higher average fixation durations in IT, but students had lower average fixation durations in the IT in comparison to DT. Interestingly, when comparing the data of students with professionals on both tasks, it was found that professionals do not always present higher cognitive effort than students. Results of average fixation duration, for instance, showed higher cognitive effort-related values for professionals, which would “challenge traditional assumptions” (p.108) about DT and IT.

By analyzing keystrokes and retrospective protocols, Ferreira (2014) carried out a study with professional translators that investigated recursiveness patterns and the production of retrospective protocols. Participants translated two sets of comparable STs, with each set comprising a text to be translated from English into Portuguese (DT) and another text to be translated from Portuguese into English (IT). The first set was comprised of texts on the same topic, whereas the second set was composed of STs on different topics. Analyses on time spent, recursiveness, and retrospective protocols, more specifically related to *lexical problems* and *spontaneous solutions versus solutions from external resources*, suggested that in the context of related texts, DT translation was more demanding than IT. However, in the context of unrelated texts, results showed that IT required more effort than DT, which indicates that in the absence of a facilitating effect, IT translation required more effort than DT. From keystroke activities, Ferreira

(2012) investigated the effects of directionality on the segmentation product of the same group of professional translators, and the results indicated that translators produced smaller segments in the IT, resulting in more segments in the IT task. As a consequence of a higher number of segments in the IT task, they produced more segments at the word level—the lower level—in the IT task in comparison to the DT task. Thus, smaller segments produced by the translators in the IT can be interpreted as an indicative of more cognitive effort in the inverse direction of translation.

Ferreira's (2013) carried out a study with eight professional translators who translated two comparable texts on the same topic and two comparable texts on different topics, from English into Portuguese and from Portuguese into English. By analyzing time, pause, recursiveness and segmentation patterns as indicators of cognitive effort, the study showed that a translator's performance is strongly related to the task at hand, when translators have to apply more effort to a specific task depending on the ST type (texts on the same topic vs. texts on different topics), as well as the task order. The results also showed that lexical solutions are more effortful during IT compared to DT. However, questions remained regarding the extent to which bilingual linguistic competence affects the task at hand, mostly in terms of lexical decisions. As studies on directionality increases, more questions arise regarding how translation is conducted in both directions and whether translation processing is affected depending on the direction of the translation.

## **2.2. Attention and cognitive effort during translation tasks**

Attention distribution during translation tasks can be measured by recording eye fixations (Dragsted 2010), assuming that a specific item which is fixated at a particular moment might indicate that that item is being processed at that time (Just and Carpenter 1980). In a study which compared eye-tracking data from reading-for-

translation task with silent reading and reading-for comprehension tasks, Dragsted showed that “professional translators *load* their cognitive capacity with something that is not only merely reading for comprehension indicating that a pre-translation takes place” (p. 47). The researcher explained that different fixation data (e.g., gaze data) can be combined with other variables (e.g., total reading-for-translation task time) to indicate different levels of cognitive “load” during a task at hand. Some variables are commonly used in TPR studies, such as total gaze time, average fixation duration, total task length, pupil dilation, among others (for a review see Hvelplund 2014).

The present study examined cognitive effort in DT and IT tasks. We investigated the coordination of attention in three areas of interest (AoI): total dwell time of fixation on the source text, on the target text, and on the external support area (available for the translators via browser). In addition, we examined time spent in each task, total fixation count and average fixation count.

### **3. Present study**

#### **3.1. Participants**

Four professional translators were recruited from an English-speaking region of Ontario, Canada. Two of the participants were highly-proficient English-Spanish bilinguals and two were highly-proficient Spanish-English bilinguals. Information from the questionnaires (see Table 1) and Verbal Fluency Measure (VFM) validated their high proficiency in both languages. In terms of their educational background, all of the participants possessed at least a bachelor’s degree and had a minimum of six years of experience with DT and IT.

*Table 1.* Participant characteristics.

	L1	L2	Translation experience (in years)	University degree	Self-reported L2 Proficiency	Frequency of DT	Verbal Fluency L1	Verbal Fluency L2
S1	English	Spanish	6-10	Yes	Very Proficient	Up to 70%	121	124
S2	English	Spanish	6-10	Yes	Very Proficient	Up to 70%	118	110
S3	Spanish	English	> 10	Yes	Very Proficient	Up to 70%	123	125
S4	Spanish	English	6-10	Yes	Very Proficient	Up to 40%	127	118

Because there are specific aspects related to each direction (e.g., editing by means of recursiveness; time; pause patterns; segmentation) that can be measured, quantitative analyses of total time spent in each task, as well as fixation time and fixation count were carried out in order to investigate whether translators applied more cognitive effort in DT or IT.

### 3.2. Procedure and design

The participants described above carried out two translation tasks, one from English into Spanish and another from Spanish into English. These tasks were recorded as a movie file and carried out separately. Only the translator and two researchers were presented during the data collection. Participants first filled in a pre-questionnaire and carried out the translation from English into Spanish. At the conclusion of the translation, the video was shown to them and retrospective protocols were recorded. Next, they translated the text from Spanish into English and retrospective protocols were recorded. The task order was the same for all participants. The STs were two popular science texts on different topics, yet similar in terms of length (Spanish ST = 180 words; English ST = 187 words) and structure according to Rhetorical Structure Theory (Taboada and Mann 2006). STs are also similar in terms of *coherence* (i.e.,



how one text span has a specific role relative to another text span) (Taboada and Mann 2006).<sup>1</sup> Translation process data was recorded with eye-tracking technology (EyeLink II) and Translog. The eye tracking data provides insight on attention directed to each of the tasks—fixation count and fixation duration. The amount of attention directed to three different parts of the screen in the same task was also analyzed. Therefore, the following variables were explored:

1. Total task length (i.e., the total time a translator spent in each task);
2. Fixation count (i.e., the total number of fixations in each task);
3. Average fixation duration (i.e., the average time that the fovea is directed at some location); and
4. Gaze time (i.e., the dwell time spent in each area of interest: ST, TT, and browser).

### *3.2.1. Eye-tracking technology and Translog*

The translation tasks were recorded with EyeLink II, a head-mounted eye-tracking device which consists of three miniature cameras situated on a comfortable padded headband<sup>2</sup>. Translation tasks were also recorded with Translog (Jakobsen and Schou 1999), a computational tool that logs keystrokes and mouse clicks during translation. Due to the space constraints, in the present paper, we will only report the results from the eye-tracking technology. EyeLink II allowed for us to calculate the total time spent on

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<sup>1</sup> For comparable reasons, original texts had to be adapted. The text in English was originally published at “A New Report Explains the Physics of Crumpled Paper,” *Scientific American*, accessed on February 5th, 2002: <http://www.scientificamerican.com/article/a-new-report-explains-the>. The original text in Spanish was entitled, “Desarrollan una lengua electrónica para producir mejor vino,” accessed on September 3rd, 2014: [http://www.bbc.co.uk/mundo/noticias/2014/01/140108\\_tecnologia\\_lengua\\_electronica\\_fabricacion\\_vino](http://www.bbc.co.uk/mundo/noticias/2014/01/140108_tecnologia_lengua_electronica_fabricacion_vino).

<sup>2</sup> More information about the system can be found in [http://www.sr-research.com/EL\\_II.html](http://www.sr-research.com/EL_II.html).

each task, total fixation count, and average fixation duration. Furthermore, fixation count in each area of interest (ST, TT, and Browser) is also analyzed to verify whether these measures can be used as indicators of different cognitive effort applied based on the direction of translation. The mean fixation duration threshold for the analysis was based on Pavlović and Jensen's (2009) study which specifies that the lower fixation threshold to discriminate fixation from non-fixation is set to a temporal resolution of 100 ms and a spatial resolution of 40 pixels, to include maximum gaze data directly related to the translation task. The EyeLink Data Viewer tool was used to display, filter, and report output of the data files.

We focused on defining three AoIs: ST, TT, and Browser. The inclusion of these AoIs was based on the idea that the potential gaze area can be the area related to ST, TT, or browser.

In order to verify fixation in each AoI, the computer screen was divided into two parts: On the left half, the Translog screen was displayed with TT and ST and, on the right half, browser was displayed so that translators could use it for external support at their convenience, such as online dictionaries, search tools, etc. Total time spent on each task was calculated with Translog. Total gaze time, fixation count, and average fixation duration were calculated for each AoI using the EyeLink II's Data Viewer tool.

### *3.2.2. Verbal fluency measure*

The ability to access words from the mental lexicon is a key component of human language processing and production, and is of great importance to psycholinguists and clinicians alike (Isacoff and Stromswold 2014). The VFM (Gollan, Montoya, and Werner 2002) is one of the most commonly used assessments of vocabulary size in bilingual studies. In the present study, participants generated as many words as possible according to specified semantic categories (clothing, country, animals, academic majors, colors, fruits, vegetables, things with wheels, musical instruments, and sports). They were given 30 seconds to do so for each category, first in

Spanish, then in English.<sup>3</sup> When adding together the total number of exemplars verbalized for each language, we are left with an arbitrary verbal fluency score. In this case study, we will investigate whether verbal fluency in either language can be used as an indicative of fluency in both languages, which might endorse information found in the prospective questionnaire on their proficiency level in both languages. As described in Table 1, overall, it seems that participants have almost the same vocabulary size in each language. Indeed, a *t*-test confirmed no significant difference between English and Spanish verbal fluency ( $t = .941, p = 0.416$ ).

### **3.3. Hypotheses**

The following predictions guided the research objectives of the present study:

- H1. Translators will spend more time and present higher fixation count during the IT task compared to the DT task;
- H2. Translators will present higher average fixation duration in the IT task than in the DT task;
- H3. Translators will invest more attention in processing the ST than the TT in the DT task. Conversely, in the IT task, they will invest more attention processing the TT than the ST; and
- H4. Translators will direct more attention to the browser during the IT task in comparison to the DT task.

## **4. Results**

### **4.1. General patterns in translation performance**

The sample size of this case study suggests that we must first caution against making sweeping generalizations based on the

results of the present study simply because small samples may not fully provide an accurate representation of a general population. Thus, we cannot assume that the data are normally distributed. We also consider the general context of translation directionality: all variables analyzed are considered to be indicative of cognitive effort, depending on the translation direction (DT or IT).

#### 4.1.1. Total time

The total time spent in each task appears in Table 2. The results show that all translators spent more time in the IT task. A *t*-test showed that the difference was significant ( $t = -2.799, p < .05$ ).

*Table 2.* Total time spent (in seconds) in each task.

	Direct Translation	Inverse Translation
S1	1,014	1,397
S2	1,034	1,268
S3	1,020	1,036
S4	1,356	1,600
<b>Mean</b>	<b>1,106</b>	<b>1,325</b>

#### 4.1.2. Total fixation count and time spent in each task

The results from total fixation showed that fixation count varied considerably among participants, in both tasks (refer to Table 3). A *t*-test showed that the difference was significant for all participants but S3 ( $t = -1.194, p = .233$ ). Total time presented in Table 3 confirmed our second hypothesis, that subjects would present higher fixation count in IT. In this sense, in terms of total fixation count, our results do not indicate that effort was be more intense in IT if we consider both total time and total fixation as measures of cognitive effort.

Table 3. Total fixations in DT and IT.

	<b>Direct Translation</b>	<b>Inverse Translation</b>
S1	1,645	2,793
S2	2,634	1,504
S3	2,002	1,830
S4	4,179	3,342
Total	10,460	9,469
<b>Mean</b>	<b>2,615.00</b>	<b>2,367.25</b>

#### 4.1.3. Average fixation duration

In terms of average fixation duration, results in Table 4 show that all participants produced longer average fixation duration in IT. Therefore, our second hypothesis was confirmed.

Table 4. Average fixation duration (in milliseconds) in each task.

	<b>Direct Translation</b>	<b>Inverse Translation</b>
S1	283	338
S2	272	258
S3	338	343
S4	223	271
<b>Mean</b>	<b>279.00</b>	<b>302.50</b>

We could assume that these participants needed to allocate more effort in the IT if we also assume that average fixation duration can be used as a measure of effort in translation.

#### 4.1.4. Areas of interest

The third hypothesis was that translators would invest more attention processing the ST than the TT in DT, which was partially confirmed by the data. Only S3 presented longer dwell time in the target text than in the source text area during DT. We had also hypothesized that they would invest more effort in the TT processing than the ST processing in IT, which was not confirmed. Total dwell time spent in Table 5 shows that participants tended to present longer dwell time in the ST area in both tasks.

*Table 5.* Dwell time spent (in milliseconds) for source text, target text, and browser.

	Direct Translation			Inverse Translation		
	ST	TT	Browser	ST	TT	Browser
S1	327060	102432	36436	442712	235220	199120
S2	253328	201172	246572	217500	115180	55688
S3	257660	329252	115004	103276	27836	11376
S4	556748	188296	205196	511296	306408	89100
Total	1170012	746556	603208	1274784	684644	355284
<b>Mean</b>	<b>292503</b>	<b>186639</b>	<b>150802</b>	<b>318696</b>	<b>171161</b>	<b>88821</b>

##### 4.1.4.1 Source text and target text

In this study, we assume that longer dwell time would indicate more attention in one specific AoI in comparison to others, which might indicate ST comprehension and TT production. Results show that during IT, all participants presented higher dwell time in the ST than in the TT, which did not confirm our third hypothesis. It appears that this group needed to allocate more cognitive resources

to ST comprehension than to the TT reformulation in the IT. Regardless the source language, results indicate that translators made more effort to decode the source language than to encode the meaning in the target language, assuming that the time spent in each AoI is an indicative of effort in translation.

We had also hypothesized that translators would invest more attention in processing the ST than the TT in the DT task. This hypothesis was partially confirmed because only S3 presented higher dwell time in the source text area in comparison to the target text area. If translators present similar patterns in both directions (e.g., focusing in the ST area more than in the TT area), it might indicate that translators attempt to make sense of the sentences and text as a whole and understanding the meaning of that ST in the original culture demands more thinking than conveying the information in the target language, as the target text, regardless the direction of the translation.

#### 4.1.4.2 Browser

Our fourth hypothesis, that translators would direct more attention to the external resources (browser) during IT, could not be statistically confirmed, as each participant present a very different pattern for in each task. Comparing the AoI's, results show that during DT participants spent longer dwell time in the ST area, followed by the browser area (except for S3). In the IT, all translators spent longer dwell time in the ST.

**Table 6. Total dwell time (in seconds) in the browser for direct and inverse translation.**

	<b>Direct Translation</b>	<b>Inverse Translation</b>
S1	36.436	199.120
S2	246.572	55.688
Total	283.008	254.808
S3	115.004	11.376
S4	205.196	89.100
Total	320.200	100.476
<b>Grand Total</b>	<b>603.208</b>	<b>355.284</b>

Results showed that most translators spent higher dwell time in the browser during their DT task, which was the opposite of what we had expected. It might be the case that vocabulary search in the DT was more demanding because translators are more critical of lexical decisions in their first language

We had hypothesized that during DT, processing the ST would be more demanding because the ST is in the foreign language, which would demand more cognitive effort to comprehend than to render the TT in the first language. Comparing only the results for ST area in DT and IT, we can confirm that participants indeed spend longer time in the ST area in the DT. During the IT, on the other hand, we hypothesized that conveying the target text in the foreign language would demand more effort. Therefore, translators would present higher dwell time in the TT area than in the ST area during the IT, and that dwell time would also be higher in the browser area during the IT, assuming that translators would need to rely more on external support during the IT than DT.



## **5. Discussion**

This case study has provided some preliminary insight on the effects of directionality by looking at patterns in translation performance. The data painted a complicated picture which presented idiosyncratic patterns related to each of the participant's performance. Returning to our hypotheses, H1 posited that translators would spend more time and present higher fixation count during IT. This prediction could not be confirmed because participants tended to present higher fixation count in the DT, even though they spent more time in the IT. Our second hypothesis, that subjects would present higher average fixations in IT, could not be confirmed because S2 presented longer average fixation during DT. However, we do find this to be true for the other three participants. Our third hypothesis, that participants would invest more effort, or attention, processing the ST than the TT during DT, was also partially confirmed. While the overall mean across participants was not significantly distinct, we do see that three out of four translators invested more attention in processing the ST than TT in DT. We had also hypothesized that participants would direct more attention towards the TT than the ST, either English or Spanish during IT. This hypothesis was rejected. During IT, more attention was directed towards the ST area compared to the TT area. All translators with the exception of S3 directed more attention towards ST in both directions contrary to what we had expected. Our results do not confirm that higher fixation in the TT area could indicate that a translator is more concerned with conveying the most accurate information to the reader than with the comprehension of the ST. It seems that translators were more concerned with understanding the source text, regardless of the language, in order to be able then to convey the information in the target text. While reading the target text, they could have been thinking about how to produce the segment in the target language, in which case the analysis of the areas of interest in an isolated fashion does not allow us to confirm whether they were indeed

thinking of the target text, or simply understanding the source text. The fourth hypothesis which predicted that translators would direct more attention to the browser during IT was not confirmed. Only S1 presented higher fixation in the browser during the IT translation task in comparison to the DT. It is important to highlight that the translators did not dedicate similar time to the external support in the tasks and that S3's fixation during DT was 10 times higher in the browser area of interest than during IT.

In this study, professional translators, regardless of the direction of the task, adapted their behavior to the task at hand in order to render the TT, directing more or less attention depending on the challenge that they were facing, and potentially focusing on the ST area while pre-translating the TT. Assuming that longer fixations on the ST or TT reflect text production problems (Carl and Dragsted 2012), it might be fruitful to investigate how two different groups of translators (English-dominant and Spanish-dominant) face similar problems during translation in both directions, and how they solve these complications. It is still not clear whether DT would require more external support research (e.g., searching by means of an internet browser) because a translation into the more dominant language would require more research than into the less dominant language simply because translators would be more critical in their first language, mostly in terms of lexical selection in L1 (Ferreira 2014). Future studies could also focus on the analysis of the final TT in order to assess whether more or less effort applied to the task can actually be observed in terms of the quality of the product output. But more importantly, studies with English-dominant and Spanish-dominant bilingual professionals in the same experiment are necessary in order to investigate effects of language dominance in the tasks and whether there is a relationship between the direction of translation and dominance.

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