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Measuring Student Translators' Cognitive Effort with Pauses: A Comparative Analysis of Human Translation and MT Post-Editing

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Abstract: Measuring the cognitive effort involved in the translation production is one of the most important issues in translation and in MT post-editing. The present study investigated student translators' cognitive effort with pauses by comparing their processes in human translation and MT post-editing. Translog II, a keyboard recording software, was used to record the translation process data. Sixteen sophomores majoring in English participated in the experiment. Mean duration of processing time and average pause duration per word under different thresholds (TG300, TG500, TG1000, TG2000 and TG5000) were used as indicators to measure cognitive effort. The results show that students translators tend to perform post-editing tasks faster than human translation, and their post-editing processes need less cognitive effort than human translation as indicated by less mean duration processing time and shorter average pause duration per word under the thresholds of 300 ms, 500 ms and 1000 ms (TG300, TG500, TG1000). It is worth mentioning that when the thresholds of pauses are longer, reaching 2000 ms or more, there is no significant difference between the two tasks for student translators. In the process of post-editing, the student translators were more concerned about machine translation text, mainly for checking and correcting machine translation errors, especially grammatical errors; while in the process of human translation, they invested more cognitive effort to understand the source text.

Keywords: Cognitive Effort, Pause, Post-Editing, Human Translation

1. Introduction

Pause and hesitation behaviour is a common phenomenon in both spoken and written language production. It is believed that pauses are indicators of cognitive processing. Therefore, researchers also associate pauses between keystrokes or mouse clicks with translators' cognitive efforts. Cognitive effort was defined by Lcruz [11] as "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". Krings' [8] pioneering study attached great importance to cognitive effort in translation process. According to this study, cognitive effort exerts a further profound influence on the temporal effort and the technical effort. It was therefore considered the most challenging to understand and is the most difficult to measure ([8, 11]). Schaeffer et al. [15] even pointed out that "a central question in translation and in MT post-editing is related to measuring the cognitive effort involved in the translation production." Based on this claim, the present study aims to investigate student translators' cognitive effort with pauses by comparing human translation and MT post-editing processes.

2. Cognitive Effort and Pauses in Translation

As has been discussed that cognitive effort, as a kind of mental processing, is harder to be measured when compared with temporal effort and technical effort. Two kinds of paradigms, the dual-task paradigm and the triple-task paradigm, were well adopted by the researchers to assess between different levels of cognitive effort in monolingual processing. It is believed that response times could be longer

when people are processing more cognitively demanding tasks. In Tyler et al.'s [18] "dual-task" experiments, the participants were instructed to press a key each time they heard the auditory signal. The study indicated that the participants who invested more cognitive effort in the item took longer time to respond. This may because they were investing more of their mental resources on the task, leaving fewer resources available to process the signal. Kellogg [7] introduced a triple-task paradigm to measure the cognitive effort in language processing. In this method, participants were told to say "stop" when they heard the auditory signal and then immediately complete a third directed-retrospection task. Key-press response times were recorded and used to assess cognitive effort. Although the dual-task paradigm and the triple-task paradigm are often used in in monolingual processing, It is also likely that the two paradigms could be used to study the effects of expertise on translation processes.

Eye tracking was used as a methodology in research of cognitive effort translation process in recent 15 years. Just and Carpenter's [5] eye-mind hypothesis suggested a straightforward relationship between what a person's eyes were fixating and what the mind was attending to and processing. It is well established that the longer the fixation time, the more cognitive effort the processing required. The number of fixations on a word or in an area is also an indication of the extent of the cognitive effort required for processing. In addition, pupil dilation increases as more cognitive effort is exerted.

Krings [8] was one of the first authors who made comments on the use of pauses in post-editing. As for the pause of individual differences, Schumacher, Klare, Cronin and Moses [16] studied the writing activities of undergraduates at different levels. O'Brien [14] researched some of the factors that affect pauses in translation, editing and post-editing. The study proposed the concept of pause rate into her work on the cognitive efforts of post-editing. Dragsted and Hansen [4] found that from English to Danish, the pause rate of interpreters and translators in written and oral translation is very different, and the pause rate of translators is higher than interpreters.

Lacruz's series studies focused on pauses and cognitive effort in translation process. Lacruz [9] introduced a new measurement indicator: the average pause ratio (APR), which is computed as the average time per pause divided by the average post-editing time per word. Studies show that APR is a useful measure of cognitive effort in post-editing ([9, 2, 3, 13]). In subsequent research, Lacruz and Shreve [10] improved and expanded the scope of the original pause ratio. They suggested a simple pause measurement PWR, which is as useful as APR in studying post-editing cognitive efforts. According to Lacruz and Shreve [10], the pause to word ratio (PWR) is the number of post-editing pauses divided by the number of words in the MT segment the ratio of the number of pauses in a segment to the number of words in the segment. In their investigation on Spanish to English machine translations, the PWR was higher when post-editors exert more cognitive effort by using a pause threshold of 500 ms.

Higher pause-to-word ratio (PWR) values are related to more cognitive effort ([10, 15]). Schaeffer et al. [15] proposed features of PWR for different thresholds in the TPR-DB. After the investigation to the correlation of Translation Difficulty Index (TDI) and pause-to-word ratio (PWR), Schaeffer et al. [15] pointed out that TDI had a significant positive effect on the PWR with a pause threshold of 5000ms. The finding indicated that both TDI and PWR were suitable predictors to measure effort in the translation process. Lacruz et al. [13] focused on literality and cognitive effort. The results showed that from-scratch translation involves more cognitive effort than post-editing process as indicated by higher PWR values.

Based on the classification of PWR by Schaeffer et al. [15], the present study tries to answer the following questions: Is undergraduate student translators' cognitive effort in human translation different from that in post-editing of machine translation? If the answer is yes, then what are the differences of cognitive effort between the two tasks?

3. Methods

16 participants were recruited to participate in the experiment. All participants were sophomores majoring in English. Their mother tongue is Chinese, and they all passed CET-4. There were 6 males and 10 females with an average age of 19-20 years. They were randomly divided into two groups, A and B, with 2 boys and 6 girls in each group. Both groups were not trained in post-editing. However, both groups were exposed to basic translation courses and possessed basic translation skills.

The six English source texts which have been used in many studies and translated into more than ten languages are selected from the multiling data in TPR-DB. Selecting the same source texts, the results of those studies can be compared across different language combinations and different translation modes.

In the present study, Translog-II was used to collect data. Translog-II is a program to record and study human reading and writing processes on a computer. Each participant was required to complete a translation task and a post-editing task. Each task consists of an average of 800 words. The post-editing texts of the two tasks were pre-translated by Baidu Translate.

Participants in group A (P01-P08) first post-edited Text 1 then translated Text 2, while participants in group B (P09-P16) first translated Text 1 then post-edited Text 2. To neutralize any skewing effects caused by differences in the texts and task sequence, we rotated the task-text combination systematically shown in Table 1.

Table 1. *The study's experimental set-up.*

Group \ Text	Text 1	Text 2
A (P01-P08)	P1	T2
B (P09-P16)	T1	P2

For each participant, logging data was collected for the two

post-editing tasks and the two human translation tasks. But the recordings of Translog-II Repaly showed that, when asked to do human translation, two participants from group A were found to have machine-translated the whole texts first and then copied the MT output to the Translog-II target window. Two other participants from group B made the wrong translation material. So the four participants' data were excluded from analysis.

4. Results

4.1. Mean Duration of Processing Time

The mean duration of processing time refers to processing time per word (Dur/TokS), calculated by dividing the total processing time of each sentence by the total number of words in the source text sentence. Table 2 presents the fixed effect of the two tasks on mean duration of processing time.

Table 2. *Fixed effect of the two tasks on mean duration of processing time.*

Fixed effect	Estimate	Std. Error	df	t value	Pr (>|t|)	Sig.
Task: P vs T	0.5749	0.2302	20.9996	2.497	0.0209	*

The result shows that the mean duration of processing time for post-editing is 2758 ms and for human translation is 4223 ms. As can be seen from Table 2, the Dur/Toks of post-editing is significantly shorter than that of human translation ($t=2.497$, $p<0.05$).

4.2. The Average Pause Duration Per Word

The average pause duration per word refers to the total pause duration per sentence divided by the number of words in the source text sentence. Under different thresholds, the pause time of each word in translation activities is different. The LMER results of average pause duration per word were presented with five different thresholds (300 ms, 500 ms, 1000 ms, 2000 ms and 5000 ms) in Table 3.

The results show that post-editing (Task P) and human translation (Task T) have significant effects on average pause duration per word under the thresholds of 300 ms ($t=6.617$, $p<0.001$), 500 ms ($t=6.777$, $p<0.001$) and 1000 ms ($t=3.551$, $P<0.001$). The pause value in human translation under this three thresholds is significantly longer than that in post-editing.

While in another two conditions (the thresholds of 2000 ms and 5000 ms), the LMER results did not show significant effects on average pause duration per word.

Table 3. *Fixed effect of the two tasks on average pause duration per word.*

Fixed effect	Estimate	Std. Error	df	t value	Pr (>|t|)	Sig.
Task: P vs T (TG300)	1.1163	0.1687	114.5128	6.617	1.23e-09	***
Task: P vs T (TG500)	1.1189	0.1651	114.9892	6.777	52e-10	***
Task: P vs T (TG1000)	0.603	0.1699	105.0322	3.551	0.000576	***
Task: P vs T (TG2000)	0.2735	0.2077	91.09331	0.229	0.819	
Task: P vs T (TG5000)	0.04354	0.19015	91.09331	0.229	0.819	

5. Discussion

The study shows that the student translators' Dur/Toks of post-editing is significantly shorter than that of human translation indicating that student translators' temporal effort of post-editing is smaller than that of human translation. This is consistent with Carl et al. [1] and Lu & Sun [13] in that the cognitive processing of post-editing was significantly faster than that of human translation. Guerberof [6] also found that post-editing was faster than human translation (although not statistically significant), and translation efficiency increased by about 25%. One possible reason for this result may be that student translators (inexperienced translators) are more likely to treat translation as a lexical processing task ([17]). With the existing MT output available, those post-editors don't have to translate all the lexical information into another language as translators do. Therefore, their main task is to correct the MT output errors so as to save some processing time for them.

The study also shows that post-editing and human translation have significant effects on average pause duration per word under the thresholds of 300 ms, 500 ms and 1000 ms (TG300, TG500, TG1000). While in another two conditions (TG2000 and TG5000), the results did not show significant effects on average pause duration per word. This means that only in short pauses condition student translators' post-editing is significantly shorter than that of human translation. As has been discussed above that higher PWR values are related to more cognitive effort. This result indicates that student translators' post-editing is less cognitively effort than their processing of human translation only in short pauses (e.g. TG300, TG500, TG1000) condition. However, when the threshold came to 2000 ms or more, such as TG2000 and TG5000, there is no significant difference between the two tasks. It shows that the cognitive effort has something to do with the thresholds of pauses. According to Lacruz [12], the shorter pauses are likely to be monitoring pauses. The cognitive effort expended in both post-editing and human translation tasks is devoted to monitoring what is being produced. In the present study, with reference to the existing MT output, student translators can save cognitive effort in monitoring what is being post-edited. However, with the difficulty growing, when student translators are faced with difficult problems, the pause duration increase accordingly. During post-editing task, there is also a need for post-editors to "completely rework areas that are unintelligible in the MT

text" Lacruz [10]. It is therefore the cognitive effort costed by the student translators has no significant differences between the two tasks (Task P and Task T).

After the experiment, questionnaires were also conducted to investigate participants' perceptions of human translation and post-editing. Regarding the difficulty, 11 students agree that human translation is more difficult than post-editing, while 5 students thought post-editing is more difficult. In terms of time allocation, student translators mention that in post-editing task, more time should be spent on checking and correcting translation errors. Meanwhile, MT output provides most of the vocabulary needed for translation, which reduces the time for them. Nine student translators have proposed that in human translation task, more time is spent on the understanding of the original text and the choice of translation strategies and methods. In terms of speed, 11 student translators support the view that post-editing can improve their translation speed. They believe that post-editing can save time and energy and make it easier for them to complete translation.

6. Conclusion

Pauses are indicators of cognitive processing and researchers associate pauses between keystrokes or mouse clicks with translators' cognitive efforts. The present study investigated student translators' cognitive effort with pauses by comparing their processes in human translation and MT post-editing. Based on the classification of PWR by Schaeffer et al. [15], the present study tries to answer the following question: Is undergraduate student translators' cognitive effort in human translation different from that in post-editing of machine translation? If the answer is yes, then what are the differences of cognitive effort between the two tasks?

The results show that students translators tend to perform post-editing tasks faster than human translation, and their post-editing processes need less cognitive effort than human translation as indicated by less mean duration processing time and shorter average pause duration per word under the thresholds of 300 ms, 500 ms and 1000 ms (TG300, TG500, TG1000). It is worth mentioning that when the thresholds of pauses are longer, reaching 2000 ms or more, there is no significant difference between the two tasks for student translators. In addition, through investigation, we know that in post-editing process, student translators pay more attention to MT output in order to check and correct machine-translated errors, especially grammatical errors. While in the process of human translation, they spend more cognitive efforts to understand the original text.

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