Syntactic Cross and Reading Effort in English to Japanese Translation

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Abstract

In English to Japanese translation, a linear translation refers to a translation in which the word order of the source text is kept as unchanged as possible. Previous research suggests that linear translation reduces the cognitive effort for interpreters and translators compared to the non-linear case. In this study, we empirically tested whether this was also the case in a monolingual setting from the viewpoint of reception study. The difference between linear and non-linear translation was defined using Cross values, which quantify how much reordering was required in Japanese translation relative to an English source text. Reading effort was measured by the average total reading time on the target text. In a linear mixed-effects model analysis, variations in reading time per participant and text type were also considered random effects. The results revealed that the reading effort for the linear translation was smaller than that for the non-linear translation. In addition, the accuracy of text comprehension was also found to affect the reading time.

1. Introduction

Linear translation is a translation strategy utilized by translators to preserve the word order of the source text to the maximum possible extent. This strategy is commonly used among English-to-Japanese simultaneous interpreters. It helps reduce the interpreter's cognitive effort and prevents their working memory from overloading (Mizuno, 2005) especially because the syntactic structures of English and Japanese mirror each other (i.e., the basic word order of SOV [subject-object-verb] in Japanese contrasts with the SVO of English). When an original English speech in S<u>VO</u> is heard and interpreted into the target Japanese S<u>OV</u>, the interpreter needs to retain the V (verb = simple predicate) in working memory until translating the following O (object).

Linear translation strategy is also said to help not only interpreters but readers of written translation. Translated texts with the use of a linear translation strategy are said to help to understand better because they "do not disrupt the flow of thought of the source text (Anzai, 1995)" and retain the "information structure" of the source text (Mizuno, 2022; Naganuma et al., 2016). Consequently, they are also thought to reduce reading effort because of the simplified syntactic complexity of the target text (Table 1)[1]. For example, the part of source and target texts in square brackets in Table 1 are relative clauses. The source text contains an accusative noun, *a book*, which is the head of a relative clause that accompanies *that Mary read two years ago*. When this source text is translated into Japanese in a non-linear manner, the relative clause is usually placed before the accusative noun in the target rendition, as shown in the example of a non-linear translation. In this case, the main clause—*Tom bought the book*—is split into two parts by the inserted relative clause, and the head of the sentence (predicate) *buy* appears at the end of the target text; therefore, the reader of the target text has to retain more information (i.e., a larger number of "chunks" that makes up the relative clause) in their working memory, resulting in higher cognitive effort in reading. Therefore, non-linear translation is more difficult than linear translation for the reader, where the inserted relative clause does not hinder the main clause. The head of the sentence also appears as early as in the source text.

To the best of our knowledge, however, no empirical investigation of reception study for the reading effort of linear translations has been carried out. This study aims to test a hypothesis as to whether linear translation takes less cognitive effort in reading without the source text being presented than non-linear translation.

Source Text	Tom bought a book [that Mary read two years ago].
Non-Linear Translation	トムは [メアリーが2年前に読んだ] 本を買った。
	Tom-Top [Mary-Nom two-years-ago-Temp read-Past] book-Acc buy-Past.
	Tomu-wa [mearii-ga ni-nen-mae-ni yon-da] hon-o kat-ta.
Back translation	Tom bought a book that Mary read two years ago.
Linear Translation	トムは本を買った。[メアリーが2年前に読んだ]ものだ。
	Tom-Top book-Acc buy-Past. [Mary-Nom two-years-ago-Temp read-Past] thing is.
	Tomu-wa hon-o kat-ta. [Mearii-ga ninen-mae-ni yon-da] mono da.
Back translation	Tom bought a book. It is the one Mary read two years ago.

Table 1. Example of an English source text and a Japanese linear and non-linear translation

2. Related Works

In translation process research, the idea of Cross, which counts how many words in the source language must be skipped to produce the subsequent word in the target language, has been used to quantify differences in syntactic structure between the source text and target text (Carl et al., 2016). Cross value is a vital indicator to define linear and non-linear translation in this study.

Carl and Schaeffer (2017) analyzed the relationship between translation literality and translation effort. They use Cross to quantify the similarity of the syntactic structure of the source text and the target text. The researchers found that translation production time increased as the translation became less linear. Furthermore, Lacruz et al. (2018) investigated the interaction of the cognitive effort during translation with semantic and syntactic remoteness between the source and target language. They quantified the syntactic remoteness with the Cross and used the pause-word ratio (PWR) as a proxy for cognitive effort. This study also found a strong positive correlation between syntactic remoteness and cognitive effort in English to Japanese translations.

Despite the number of studies investigating the relationship between syntactic Cross and cognitive effort needed for translators, few studies have focused on translation readers' perception in terms of reading cognitive effort and compare the linear vs. non-linear translations. Some studies have briefly discussed cognitive effort in linear translation by exploring the related process of sight translation. The pilot experiment of Yamada and Naganuma (2019)—wherein

[1] The gloss used in this paper is as follows: Top=Topic, Nom=Nominative, Temp=Temporal, Acc=Accusative, Dat=Dative

translation process data collected for English to Japanese sight translation were compared by Cross value between linear and non-linear translation—found that the Cross value produced during sight translation was close to that of linear translation (Yamada & Naganuma, 2019, p. 98).

Hirose (2003) focused on prosodic structure and how it affects readers' selection of a particular reading from different options when reading a Japanese sentence containing relative clauses. That is, a sentence with high Cross value is more likely to produce a cause ambiguous reading, increasing reading effort. An example of syntactic ambiguity caused by the syntactic properties of Japanese is cited below (Hirose, 2003, p. 168).

(1) 森下が<u>新薬</u>を心から**信用した**友人達に
Mori'sita-ga <u>si'nyaku</u>-o kokoro'kara **sinyoosita** yuuji'ntati-ni
Morisita-Nom <u>new medicine</u>-Acc truly **trusted** friends-Dat

In example (1), the verb *si'nyoosita* (trusted) (bold) remains syntactically ambiguous until the reader sees *yuuji'ntati* (friends). Until then, other interpretations such as "Morishita truly trusted new medicine" are possible. Furthermore, the ambiguity of *si'nyaku* (new medicine) (underlined) is not resolved until the reader sees the predicate that follows *friends*.

(2) 森下が[新薬を心から信用した]友人達にとうとう会った。
Mori'sita-ga [si'nyaku-o kokoro'kara sinyoosita] yuuji'ntati-ni to'otoo a'tta.
Morisita-Nom new medicine-Acc truly trusted friends-Dat finally met

In (2), the predicate is a transitive verb *a'tta* (meet). In this case, syntactic ambiguity with the relative clause is determined as indicated by the square brackets.

Nakamura and Arai (2012) measured the effort in reading Japanese garden-path sentences using an eye tracker, showing that the cost of reanalyzing Japanese garden-path sentences is high and that the effort might reflect the degree of the reader's commitment to first-pass reading.

In sum, complex syntactic structures with high Cross values are likely to affect readers' cognitive effort, as non-linear translation likewise may be cognitively taxing; however, it is expected that linear translation may produce an opposite result.

3. Research Question and Experimental Settings

3.1. Research Question

This study is a reception study that examines whether translated texts using a linear translation strategy, resulted in smaller Cross value, will reduce reading effort, compared to the case where they are tasked with reading non-linear translation (with higher Cross value). To this end, we carried out an empirical experiment to collect data on reading effort from different readers. The experiment settings and our definition of reading are described below:

- Readers are people who routinely read Japanese texts, regardless of their native language.
- They read only the target text (i.e., the source text is not presented).
- They read silently, aiming to comprehend the content of the text.

The research question of this study is as follows:

Is the reading effort of linear translation lower than that of non-linear translation?

TO test the research question, we prepared linear and non-linear translations, asked 15 participants to read them, and collected the gaze data from reading them using an eye tracker.

3.2. Metrics to measure the reading effort

We prepared two types of translation for each source text: linear and non-linear. To determine the difference between the linear and non-linear translation, we used the Cross value and Cross rate proposed by Okamura and Yamada (2020). These metrics quantify differences in syntactic structure between source and target texts in a similar way as Cross in Carl et al. (2016); however, they are calculated in chunk units (minimum syntactic unit of meaning) rather than word units (for a detailed definition of chunks, see Okamura and Yamada, 2020).

We also drew on the concept of Normalized Total Reading Time on the Target Text (nTrtT; see Ogawa, 2021) to examine the cognitive effort of reading; however, we divided the reading time by the number of words[2] in the target text rather than the source text. A longer reading time suggests a higher cognitive effort. In our study, reading time is the total fixation duration captured by an eye tracker. The research question, therefore, can be paraphrased as follows: Is the nTrtT value (i.e., reading effort) of a target text with a small Cross value (i.e., linear translation) lower than that of a target text with a large Cross value (i.e., non-linear translation)?

3.3. Participants

We recruited participants who had completed three or more years of undergraduate study with relatively high command over both English and Japanese. A total of 15 participants joined the experiment: 10 native Japanese speakers and five native speakers of other languages, including English, Russian, Thai, and Spanish. Although we did not establish any standards to control the participants' English and Japanese language skills, the average TOEIC® Listening & Reading Test score was 814.09 only for those who responded to the post-experiment survey. Three of the native speakers of the other languages obtained Level 1 proficiency in the Japanese-Language Proficiency Test. Since variation in reading performance among the participants occurred in any case and was considered in the analysis, we considered it a reasonable profile of the participants.

3.4. Experimental Texts

The experimental texts were prepared in the following way. First, we collected general English online news articles that had already been translated into Japanese (approximately 150 characters, three to five sentences). For a particular sentence in the article, two versions of translation were prepared: linear and non-linear. The sentence with two types of translations is called an “experimental segment,” which is targeted for analysis. No changes are added except for the target segment. The criteria for the experimental segment were as follows: 1) the number of chunks (Okamura & Yamada, 2020) must be at least seven, and 2) the segment must contain a restrictive relative clause (Mizuno, 2022).

For the experimental segment, two patterns of linear and non-linear translation were prepared by changing only the function words and the position of the content words. The criteria for linear translation were as follows:

[2] The word is the smallest unit in a sentence when it is separated by the Japanese morphological analysis tool, MeCab (Kudo et al., 2004).

1. The antecedent is translated first, followed by the restrictive relative clause.
2. Cross value and Cross rate are less than double those of non-linear translation.

The criteria for non-linear translation are as follows:

1. The restrictive relative clause is translated first, followed by the antecedent.
2. Cross value and Cross rate are more than double those of linear translation.

The linear and non-linear translations prepared by these criteria are distinguished in the analysis by the categories J for *junokuri* (linear translation) and G for *gyakuokuri* (non-linear translation). The variable name for this distinction is JvsG in this study.

Four sets of texts (articles) were prepared in the same manner. One of the four texts was used for practice and the other three (i.e., Texts 1, 3, and 5) for data collection. The variable that identifies these texts is named OriginalText.

3.5. Experimental Procedure

The experiment was conducted in the following steps.

1. Orient each participant to the experiment's flow and the text's outline displayed on the computer screen.
2. Calibrate and validate the eye tracker.
3. Present the target texts on the screen.
4. Conduct a comprehension test after each reading.

We used Translog-II (Carl, 2012b) to display the experimental texts in step 3. The order in which the texts were displayed was randomized for each participant. A simple comprehension test (two questions about the content) in Step 4 was conducted to secure the quality of each reading. It consisted of two correct/incorrect questions about the content of the texts (created with reference to Royer et al., (1987)). The test results were used in a statistical analysis as a three-level categorical variable (hereafter referred to as Test). *Zero* refers to no correct answer out of two questions, *Half* to one correct answer, and *Full* to two correct answers. The overall percentage of questions answered correctly was 83%. The data collected through these procedures was uploaded to the CRITT TPR-DB[3] (Carl et al., 2016). After aligning the source and target texts, the tables were generated for analysis (only the experimental segments were used for analysis).

4. Results and Discussion

4.1. Quantitative analysis using Linear Mixed-Effects Models

Figure 1 is a boxplot visualizing the differences in nTrtT for each participant. The part on the x-axis refers to the 15 participants. For example, the participant named P08 tends to spend more time reading the target segments than the other participants. In contrast, P05, P12, P13, and P15 read the target segments in a relatively short time. Thus, the reading time varies significantly among the participants, which should be considered in subsequent statistical analyses. Figure 2

[3] Translation Process Research Database of the Center for Research and Innovation in Translation and Translation Technology (https://sites.google.com/site/centretranslationinnovation/tpr-db)

is a boxplot showing nTrtT for each text, where the OriginalText on the x-axis refers to the text number (Texts 1, 3, and 5). This figure shows that reading time among the texts differs significantly.

These figures indicate that the participants and texts may affect the reading time of the linear and non-linear translations. In other words, since there is a considerable variation in the reading time depending on the participants, and the differences among the three experimental texts (e.g., the differences in topics in each article) affect the reading time (i.e., cognitive effort), it may be difficult to see whether the difference between the linear and non-linear translation affects the reading time. Based on these results, the following statistical analysis was conducted.

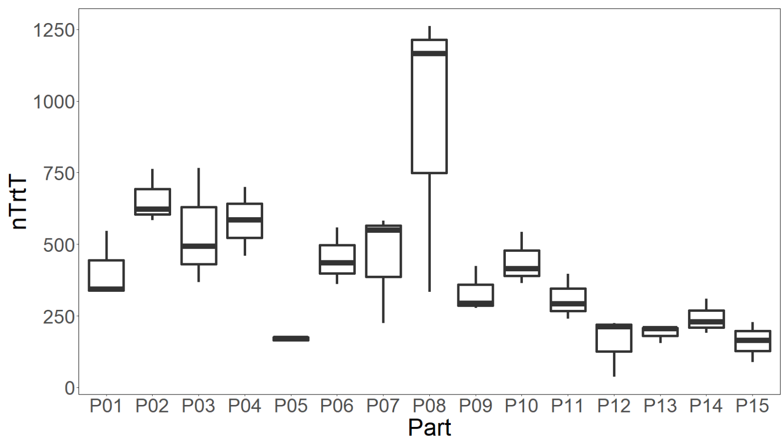

Figure 1. nTrtT for each participant

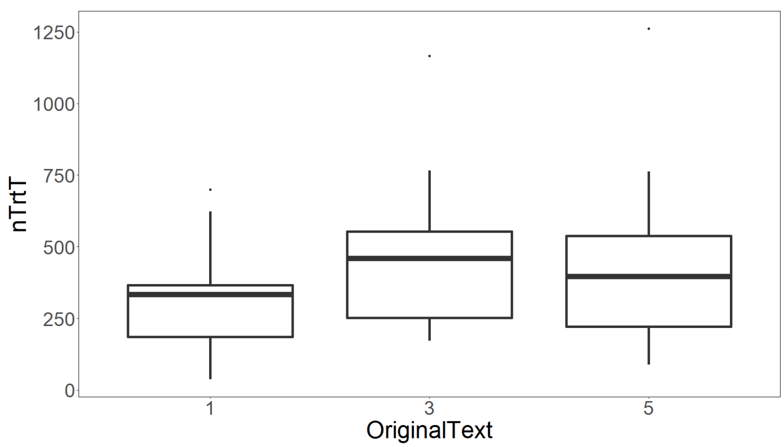

Figure 2. nTrtT for each text

We used linear mixed-effects models[4]; nTrtT was the outcome variable. In addition, two variables, Part (participants) and OriginalText (experimental texts), were included as random effects, which are reflected only in the intercept; this allows us to consider that the average

[4] Statistical analysis was performed on R (version 4.1.2 (R Core Team, 2021)) and RStudio. lme4 (Bates et al., 2015), lmerTest (Kuznetsova et al., 2017), sjPlot (Lüdecke, 2021), and ggplot2 (Wickham, 2016) were used.

reading time may vary depending on the individual participant and the text type. The predictors were selected from several candidates: Cross values, Cross rate, JvsG (difference between linear and non-linear translation), Test (results of comprehension tests), number of chunks, Japanese readability score, and Flesch-Kincaid Grade Level. We tried combinations of these predictors and selected the model with the lowest AIC.

	nTrtT			
Predictors	*Estimates*	*std. Error*	*CI*	*p*
(Intercept)	373.14	69.60	232.24 – 514.05	**<0.001**
JvsG [G]	101.59	40.93	18.74 – 184.44	**0.018**
Test [Half]	-29.81	53.33	-137.78 – 78.16	0.579
Test [Zero]	-303.99	83.93	-473.90 – -134.07	**0.001**
Random Effects				
σ^2	13753.54			
$\tau_{00\ Part}$	48673.89			
$\tau_{00\ OriginalText}$	1920.37			
ICC	0.79			
N_{Part}	15			
$N_{OriginalText}$	3			
Observations	45			
Marginal R^2 / Conditional R^2	0.125 / 0.813			

Table 2. Summary of JvsG + Test model

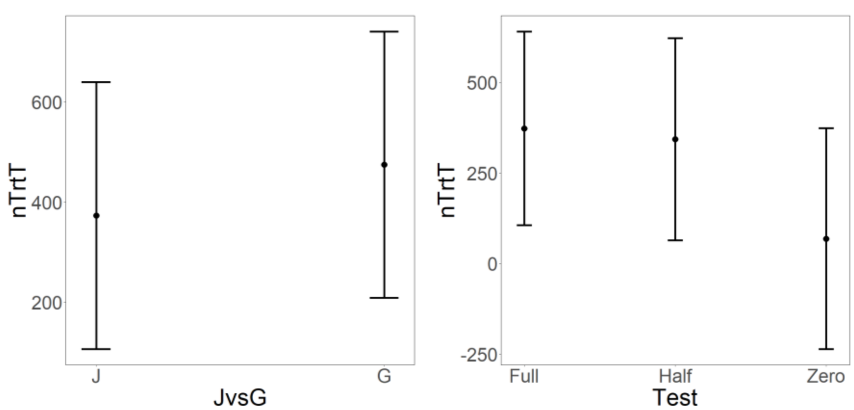

Figure 3. Plots of JvsG + Test model

Consequently, a model with JvsG and Test as predictors was selected. Table 2 summarizes the model, and we can discern two points from the top part of the table. First, the reading time for the non-linear translation was significantly longer than that of the linear translation for the participants who answered both questions correctly on the comprehension test. Second, among participants who read the linear translation, those who answered either one or both questions correctly on the comprehension test had significantly longer reading times than those who answered none correctly. The results of this model are plotted in Figure 3. The left plot shows that reading time tends to be shorter for the linear translation than for the non-linear translation. The right plot indicates that participants who performed better on the comprehension test (i.e., those who read and understood the text well) tended to spend more time reading the target text. These results suggest that linear translation requires less reading effort than non-linear translation.

The bottom part of Table 2 also indicates that random effects contribute significantly to this model. The intraclass correlation coefficient (ICC) shows that 79% of the variance is explained by the random variables, suggesting that using a linear mixed-effects model was appropriate. In addition, since Conditional R2 is large compared to Marginal R2, random effects contribute significantly to the model. Marginal R2 refers to the proportion of variance explained by the predictors (i.e., JvsG and Test), while Conditional R2 refers to the proportion of variance explained by these two predictors and two random variables (i.e., participants and text type).

4.2. Qualitative analysis using progression graphs

Since the statistics above show differences in reading cognitive effort between linear and non-linear translation, we created progression graphs visualizing reading processes involving regression or complex behaviors. Progression graphs enables analyzing translators' activity data. It represents the distribution of gaze activities over time (e.g., Carl, 2012a; Carl and Kay, 2011). As shown in Figure 4, the x-axis represents time progression, indicated by timestamps in ms, while the y-axis (on the right) represents Japanese target words. The target text begins at the bottom of the y-axis and ends at the top. Figure 4 shows excerpts from the readings of two participants (P10 and P15) who were reading the experimental segment of Text 1. The left plot shows P10 reading the linear translation, and the right plot shows P15 reading the non-linear translation. The black dots are fixations, and the black lines connecting them are saccades. Red lines across the graph indicate breaks of chunks (see Okamura and Yamada, 2021). In general, when the graph rises smoothly toward the right upper corner with small numbers of fluctuations, one can summarize that there is a lower degree of cognitive effort involved in the participant's reading.

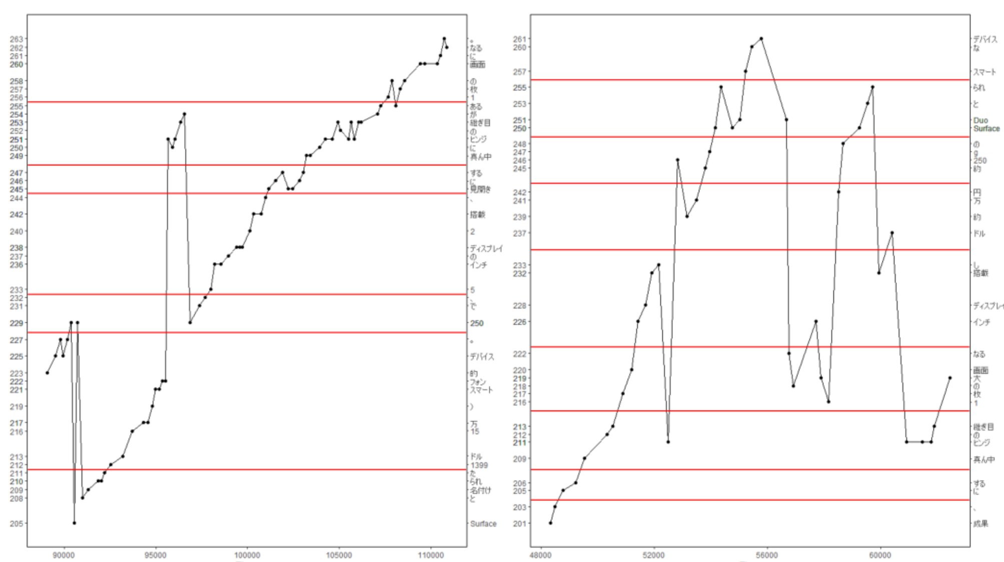

Figure 4. Progression graphs of P10 reading a linear translation (left) and P15 reading a non-linear translation (right)

P10 (left), reading a linear translation, reads the target text relatively progressively. In contrast, P15 (right), reading a non-linear translation, frequently re-read the previous part of the sentence across chunks.

In particular, in the non-linear translation (right), the participant seems to read the entire sentence once before 56,000 ms, and after 56,000 ms, the participant re-reads it by going back and forth between the parts of the sentence read once before. It is evident from these observations that the syntactic complexity of non-linear translation may require the reader to re-read the target text.

The relationship between progression graphs and linear translation needs further investigation because the difference observable in Figure 4 may be due to the idiosyncracies among participants.

5. Conclusion

This study investigated the relationship between linear translation and readers' cognitive effort. Linear translation in this study was defined as having a relatively low Cross value and Cross rate (Okamura & Yamada 2020). In a non-linear translation, the Cross value and Cross rate are relatively high. We prepared texts containing linear or non-linear translations and conducted reading experiments using an eye tracker to measure the readers' cognitive effort. Total reading time was used as a metric of cognitive effort. We then examined what factors influenced the reading time, including Cross value, Cross rate, JvsG, and the results of a comprehension test, while also considering uncontrollable factors due to the variation among participants and experimental texts. The results revealed that the type of translation (linear or non-linear) and the comprehension test results significantly impacted the reading time. In addition, qualitative analysis of the progression graphs suggested that non-linear translation is likely to be read more regressively than linear translation.

The research question is, "Is the reading effort of linear translation lower than that of non-linear translation?" The results of this study indicate that the reading effort of linear translation is lower than that of non-linear translation. Moreover, to explain the reading time used as a measure of effort in this study, it is necessary to consider the type of translation and also the comprehension of the text. This result is proof of our intuition that reading time is longer for those who read with a correct understanding of the text, but we realized the necessity of improving the ecological validity of the experiment by fully specifying the purpose of the reading for participants. Furthermore, some translation studies have shown that cognitive effort depends on the purpose of reading (Jakobsen & Jensen, 2008; Ruiz et al., 2008). Therefore, we would like to continue research to measure cognitive effort after encouraging reading with comprehension rather than just following the text.

One of the limitations of this study is the considerable variation in reading times across texts. As indicated by the bottom part of Table 2, even in the best model finally employed in this study, the random variables had higher explanatory power than the predictors. Although it is impossible to control the variation in participants' reading, the texts used in the experiments must be reconsidered. By collecting more data from more participants, we would like to continue investigating what contributes to the cognitive effort.

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