Effect of word order asymmetry on the cognitive load of English–Chinese sight translation

Evidence from eye movement data

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This article examines word order asymmetry as one prominent obstacle in the cognitive process of English–Chinese sight translation. A within-subject experiment was designed for 23 MA translation students who sight translated sentences with different degrees of structural asymmetry from English into Chinese in both single sentence and discourse contexts. To measure cognitive load, participants' eye movements during translation were recorded using an eye tracker. Three major findings were generated: (1) The effect of word order asymmetry was confirmed on both sentence-based and word-based processing; (2) Contextual information did not contribute to less effortful processing in the discourse context (as indicated by more fixations and longer regressions); (3) Segmentation was used far more frequently than restructuring to address asymmetric structures. We expect these findings will enrich our understanding of the cognitive mechanisms involved in interpreting between languages that are structurally very different and help inform training practices.

Keywords: word order asymmetry, cognitive load, English–Chinese sight translation, eye movement

Introduction

Impact of word order asymmetry on interpreting

Whether language-specific differences pose additional constraints has been a question of significant debate in interpreting studies. 'Universalists' (Setton 1999), represented by the Paris School, assume that interpreting is a language-independent process (Lederer 1999; Seleskotvitch 1984): interpreters are not influenced by language-pair-specific factors such as structural differences between source language (SL) and target language (TL) as long as they are highly proficient in both languages and can apply *deverbalization*, a sense-based approach that prioritizes meaning rather than focusing on surface language properties (Seleskotvitch 1978). In contrast, the 'Bilaterists,' represented by the Information Processing School, consider language-pair specificity a prominent obstacle in interpreting (e.g., Gile 2005; Zanetti 1995): there is always some impact resulting from SL surface structure (Donato 2003), and this may increase cognitive workload and cause more frequent errors, resulting in "a crisis of resource management for the interpreter" (Li 2015: 181). One typical indicator of language specificity is word order asymmetry (Gile 2005): the degree of similarity between SL and TL in word order may have the effect of either increasing or decreasing cognitive load during interpreting (Li 2015). If the language combinations are syntactically distant, interpreters must devote greater effort to coordinating syntactic disambiguation, information storage, and reformulation (Christoffels, de Groot, and Kroll 2006).

Many studies have been devoted to investigating the effect of word order asymmetry on interpreting. Earlier explorations have concentrated on product analysis by identifying structure-related problems and the strategies required to cope with the asymmetry (e.g., Ahn 2005; Riccardi 1995; Wliss 1978). Recent years have witnessed a growing interest in experimental or corpus-based approaches to word order issues in interpreting (e.g., Liontou 2011; Seeber and Kerzel 2012; Wang and Gu 2016). Cumulative evidence has been obtained that supports the negative impact of word order differences on interpreting performances as reflected in unnatural pauses (Wang and Gu 2016), lower accuracy and speed (Lee 2002; Seeber 2001), and the use of language-specific strategies (Donato 2003; Guo 2011). There is also an emerging trend of probing into the interpreting process and examining the role of structural difficulty from a cognitive perspective. For example, Seeber and Kerzel (2012) investigated the impact of morphosyntactic asymmetry between SL and TL on the process of simultaneous interpreting (SI). Professional interpreters were asked to interpret German verb-initial (syntactically symmetric) and verb-final (syntactically asymmetric) constructions into English, and their task-evoked pupillary responses were measured during the task. Based on the cognitive load models of SI, they predicted higher cognitive load in terms of pupil dilation through the processing for the asymmetric constructions as the syntactic asymmetry elicited an increase of cognitive load in later period of interests. Asymmetry-induced differences became more pronounced as the source construction unfolded. The data analysis revealed a lack of significant effect of syntax or period of interests, but the effects of syntax became stronger at the later period of interests. The results indicate a moment-to-moment change in cognitive load during the interpreters' real-time processing and an increase in cognitive input downstream triggered by syntactic asymmetry.

Although the problems and/or difficulties due to word order asymmetry have been evidenced by empirical studies, the degree of its influence largely depends on language combinations. Interpreting becomes much easier if aspects of syntactic representation in the two languages are closely related (Maier et al. 2017). For instance, Gile (2011) compared the outputs in SI among French, German, and Japanese renderings of the same English source speech and found that there were more omissions and errors in the Japanese renditions than in the others. The result indicates that interpreting between typologically distant languages involves greater cognitive load and entails greater risk of errors.

Word order asymmetry in English–Chinese interpreting

Chinese is one of the six UN official languages and a major non-European language widely adopted in conference interpreting. Chinese is a topic-prominent language with a relatively free word order. The way words are governed depends largely on the topic or semantic meaning rather than on the grammatical rules (Li and Thompson 1981). In contrast, English has a more rigid syntax and fixed word order. Setton (1999) considers syntactic differences between Chinese and English a prominent obstacle in interpreting that warrants further investigation. Several studies, most of which are based on a product-oriented approach, have been carried out to examine this issue. For example, Dawrant (1996) observed the strategies adopted by professional interpreters to address Chinese-specific structures in Chinese–English SI and found that interpreting these structures caused additional challenges and required capacity-saving strategies such as anticipating, waiting, and chunking. With a focus on right-branching structures in English and left-branching structures in Chinese, Wang and Gu (2016) collected on-site English–Chinese interpretations of the same speech by three professional interpreters and analyzed errors, pauses, and information loss in their outputs. Adopting a similar corpus-based approach, Wang and Zou (2018) examined how front-loaded modifying structures in Chinese were rendered into English by professional interpreters. Data results showed that reordering was primarily used to address structural asymmetry and induced greater cognitive pressures. These product-oriented studies have demonstrated the impact of word order divergences on interpreting performance and the specific strategies required to deal with the asymmetry-induced difficulty.

Two specific structures – i.e., relative clauses (RC) and passive constructions (PC) – are examples of word order asymmetry and potential obstacles for interpreters (Setton 1999; Qin and He 2009). Both English and Chinese frequently employ RC, but the syntactic properties are strikingly different between the two languages. In terms of correlations between head nouns and modifiers, English and Chinese conform to divergent branching directions (Setton 1999). As shown in Example 1, in the source sentence, the RC follows the head noun as post-modifier whereas in its Chinese version, this modifying structure precedes the head noun. Additional effort may be required during English–Chinese interpreting if interpreters reorder English sentences with RC to comply with the rules of Chinese. And this reordering may become more difficult if the original RCs are embedded with long and complex inner structures (Shlesinger 2003; Wang and Gu 2016).

Example 1. (with RC in bold)
SL: Addressing the migration crisis is an enormous challenge which all European countries should face up to and work hard to resolve.
TL: 解決移民危機是一個**所有歐洲國家都應直面并努力應對的**巨大挑戰
[Back translation: Addressing the migration crisis is an all European countries should face up to and work hard to resolve DE enormous challenge.]

Example 2. (with PC in bold)
SL: Our foreign policy is supported by people all over the world.
TL: 我們的外交政策**受到了世界各地人民的支持**
[Back translation: Our policy gets people all over the world DE support.]

Similarly, PC is another potential problem trigger in English–Chinese interpreting. In both languages, 'be + passive verb' is the canonical order for PCs (Xiao et al. 2006). The major difference between English PCs and Chinese PCs lies in the correlations between passive verbs and agents. In English, the agent is always located after the passive verb (Xiao et al. 2006), while in Chinese, the agent consistently precedes the passive verb (Chappell and Shi 2016). Example 2 shows how the original English PC has to be reordered when translated into Chinese, a process that requires an interpreter's relocation of the agent and implies greater mental load.

Cognitive load and processing word order asymmetry in sight translation

One important task in peeking inside the "black box" of interpreters is studying the cognitive mechanism that allows for multi-tasking simultaneity. Cognitive load has been the conceptual basis for explorations into cognitive aspects of interpreting (Chen 2017; Seeber 2011). The construct of cognitive load was first discussed in the field of psychology with the underlying assumption that the cognitive resources in the human brain available for processing certain tasks were limited (Miller 1956). It was later introduced to studies of interpreting to better understand the cognitively demanding features of interpreting. According to Giles' (2009) Tightrope Hypothesis, interpreters work close to saturation in terms of cognitive load requirement. Specific task and environmental characteristics such as language pair and textual/speech features may further constrain the cognitive resources available to them (Chen 2017). Cognitive load is thus used as an indicator of processing difficulties in interpreting. Since cognitive load is essentially conceptual, it can only be analyzed in terms of observable and measurable indicators such as an interpreter's subjective feelings, interpreting performance (e.g., errors, pauses or self-repairs), and psycho-physiological responses (eye movement, brain functions or cardiac system; Chen 2017; Paas et al. 2003). One frequently used method to capture interpreters' real-time cognitive load is eye tracking, which allows for moment-to-moment recording of real-time processing in language tasks such as reading and translation (Hvelplund 2017; Rayner 1998; Seeber 2013). Eye movements, including fixations and saccades, have been theorized as indicators of cognitive load during language processing. The analysis of eye movements offers new insights into the mental activities of translators and interpreters (Hvelplund 2017). Popular eye measures used in relevant studies to examine overall processing at sentence or text level include gaze duration, average fixation duration and pupil size (e.g., Seeber and Kerzel 2012; Shreve et al. 2010). Word-based measures such as first fixation duration, regression count and regression path duration are informative of mental activities during different stages of processing (Yan et al. 2013).

Eye tracking has been used to measure the cognitive load relating to syntactic divergences in sight translation. Sight translation (STR) generally refers to the oral translation of a written text (Čeňková 2015). Similar to SI, STR requires concurrent comprehension and production. Thus, STR has been considered a special variant of interpreting (Pöchhacker 2004). According to Agrifoglio (2004), interpreters during STR may encounter greater risk of cognitive overload due to constant interference from the written source information. This interference generally takes the form of complex grammatical or syntactic structures and can be stronger when SL and TL are structurally distant (Gile 2009). To examine the relations between syntactic processing and cognitive load, Shreve et al. (2010) used eye tracking to investigate the effect of increasing syntactic complexity on cognitive load during STR and written translation. The findings demonstrated that STR was sensitive to syntactic manipulation and that the processing of complex syntax generated greater cognitive load than the processing of non-complex syntax. Focusing on the constructional mismatch between SL and TL (i.e., translating language-specific constructions into a TL without such constructions), Rojo and Valenzuela (2013) examined eye movement patterns when participants sight translated English resultative and non-resultative constructions into Spanish, a language which does not have resultative structures. The processing of the resultative constructions was found to be more effortful in terms of total gaze time, mean number of fixations, number of regressions, and pupil changes. In a recent eye-tracking study, Chmiel and Lijewska (2019) researched syntactic processing in STR by professional and novice interpreters. Participants sight translated both subject-relative clauses and object-relative clauses from English to Polish. Their analysis of eye movements showed that the structurally more difficult object-relative clauses were viewed for a significantly shorter time than were the subjective-relative ones. This result was attributed to the interpreters' tendency to avoid textual interference, thus lessening the level of coordination effort required.

Two recent studies on sight translation have examined eye movements relating to structural differences between English and Chinese. Su and Li (2019) demonstrated that language-pair-specific structures were cognitive problem triggers in English–Chinese STR in both directions. The contrast of head-initial noun phrases in L1 STR and head-final noun phrases in L2 STR was detected to demand greater cognitive load in terms of visit duration and first fixation duration as well as errors or disfluencies in the outputs. In another eye-tracking study of English–Chinese STR, Ho (2017) distinguished two types of principal branching direction (PBD), namely left-branching structure in Chinese (the modifier preceding the modified) and right-branching structure in English (the modifier following the modified). He predicted that the processing of the SL parts in which PBD differed from the TL would result in longer fixation durations than for the processing of non-PBD parts. However, his statistical analysis showed that no significant differences in eye measures were observed in the cases of either professional or novice interpreters. One possible explanation for this was the degree of SL manipulation and the small size of the units under examination. In Ho (2017), there was also no prior control of source stimuli in terms of syntactic patterns. He merely marked modifiers as PBD units and non-PBD units in the source texts before conducting cognitive load analysis. Additionally, most of the units, both PBD and non-PBD, were words or phrases. However, the asymmetry effect was likely to show up not only on these units but also on words preceding or following them. As Clifton and Staub (2011) pointed out, syntactic difficulties can occur at different points in eye-tracking records. If wider regions surrounding the target units were to be inspected, it is possible that a more significant effect of word order asymmetry would be observed, as measured by the eye parameters.

Summary

Both product-oriented and process-oriented studies have offered evidence for a strong impact of word order asymmetry on interpreting. Word order asymmetry is responsible for an increase in cognitive load, the use of language-pair specific strategies, and errors or problems in delivery. Additionally, the bulk of relevant studies that investigate structural asymmetry in English/Chinese interpreting, while supported by performance measures, have been critically lacking in real-time data. Only recently has cognitive processing relating to word order differences drawn researchers' attention. Furthermore, few experimental studies have looked specifically at word order asymmetry as an independent variable through the manipulation of source materials. For example, the experimental design of Ho's (2017) study included reading mode (reading for comprehension, reading aloud, and sight translation) and level of interpreting expertise (professional interpreters, novice interpreters, and bilinguals) as two independent variables but only studied the cognitive load involved in PBD units processing during sight translation as supplementary data. Lastly, despite the richness and depth of eye-tracking data, eye movement measures in most related studies are confined to fixation durations and fixation counts as indicators of overall cognitive load. Few attempts have focused on whether and how cognitive load during English/Chinese STR is influenced by word order asymmetry at different processing levels or through different processing stages.

Against this backdrop this study investigates the effect of word order asymmetry from a cognitive perspective by manipulating the degree of structural difficulty and the availability of context during English–Chinese sight translation. It was expected that the impact of word order asymmetry could be modulated by a variety of factors, such as task conditions and interpreting expertise. For example, providing interpreters with greater amounts of contextual information may alleviate the cognitive load resulting from structural difficulty. Ample evidence from previous studies confirms that a supportive context during reading facilitates word recognition and processing (e.g., Rayner 1998). Words are recognized more quickly when preceded by a related word or sentence than when processed in isolation or in a neutral sentence (Fischler and Bloom 1985). Contexts with semantic association speed up reading by supporting the integration of the current word into readers' discourse representation (Schustack et al. 1987). Additionally, contextual support is critical for inference processing: contextual information helps to activate readers' world knowledge and to establish logical links between individual parts, which in turn facilitates on-line anticipation, thereby alleviating the cognitive load during reading (Johnson-Laird 1983; Van Dijk and Kintsch 1983). Considering these contextual benefits in reading, cognitive load during interpreting will likely be modulated by contextual information: processing in wider contexts can to some degree offset asymmetry-induced mental disruption. Interpreting sentences embedded in discourse is less effortful than interpreting sentences in isolation, as interpreters are generally encouraged to apply a more sense-based approach, reducing their dependence on the surface structures of the SL.

Research questions

With a focus on the effect of word order asymmetry on cognitive load during sentence processing, this study explores the following questions:

1. What are the effects of word order asymmetry on the cognitive process of English–Chinese sight translation?
2. Does cognitive load, as indicated by eye movement measures, differ between asymmetric and symmetric word order?
3. Does cognitive load, as indicated by eye movement measures, differ between sentences read in isolation and sentences read in the context of a wider discourse?
4. Are interpreters more likely to apply restructuring or segmentation strategies when interpreting asymmetric word order?

Method

Participants

Twenty-three postgraduates (two males; $M = 23$ years, $SD = 1.2$) enrolled in a two-year translation and interpreting program at MA level were recruited. All the participants had a similar language background, and all had completed at least 12 weeks of intensive training in interpreting. All claimed Chinese as their A language and English as their B language. To ensure a high degree of proficiency of English, only those who had scored 6.5 or higher on the International English Language Testing System (IELTS) exam were invited. The results of background questionnaires showed that all students were qualified to participate. Additionally, the participants were required to self-assess their proficiency in L2 reading and speaking, two critical components of STR. Proficiency was measured on a scale ranging from 1 (not proficient) to 10 (highly proficient). Results demonstrated that all participants were highly proficient in L2 reading ($M = 8.23$, $SD = 0.45$) and fluent L2 speakers ($M = 7.6$, $SD = 0.9$). All had normal or corrected-to-normal vision.

Design and materials

Two types of experimental sentence were adopted for the sight translation task: asymmetric and symmetric sentences. Each asymmetric sentence contained one RC or PC structure. Each symmetric sentence was similar to Chinese in terms of word order, which can be interpreted by following the original structure. The participants processed the sentences in two task conditions: single sentence context and discourse context. In single sentence context, the experimental sentences were presented in isolation. In the discourse context, the sentences were embedded in flowing discourses, and the participants interpreted two coherent discourses that contained the experimental sentences. The essential difference between the two task conditions was the amount of contextual information.

Sixteen (16) experimental sentences were employed for the single sentence condition: eight were asymmetric (four containing RC and four containing PC), and the remaining eight were symmetric. All sentences were adapted from English speeches taken from authentic interpreting settings and were related to topics with which interpreting trainees were familiar. For the discourse condition, two source texts of similar length (Appendix A) were constructed to obtain an equal number of appropriate experimental sentences, and each text contained two RC sentences and two PC sentences, respectively. Ideally, these texts would have been extracted from an existing corpus of real interpreting settings. However, using authentic materials proved impracticable since the original sentences need to be manipulated to comply with the research purpose and experimental design. Therefore, measures were adopted to offset the texts' artificiality: both texts were selected from authentic speeches written for oral delivery. To meet the stimuli criteria, some sentences were reformulated to change their syntactic structures while retaining the semantic meaning. Every two experimental sentences in the text were separated by one filler to avoid spillover effects. Four interpreting teachers from a Hong Kong university assessed the coherence of the two adapted source texts on a five-point scale (1: very low coherence; 5: very high coherence). The original scores for Text A by the four raters were 4, 5, 5, and 5, while all raters scored five for the second text. These demonstrated that the adaptation did not affect textual coherence.

The asymmetric and symmetric sentences were matched across conditions in terms of sentence length (21 words), word length (number of letters in each word), and word frequency. The statistical tests revealed no statistically significant differences between the mean word length of asymmetric sentences ($M = 4.97$, $SD = 0.15$) and that of the symmetric ones ($M = 5.03$, $SD = 0.25$, $t[30] = 0.5$, $p = 0.62$). Linguistic profiling of the experimental sentences was conducted using *Vocabprofile* (Cobb 2002). The results showed that 81.9% of words in the asymmetric sentences and 80.5% of words in the symmetric sentences were ranked in the 1000- and 2000-word frequency bands in English. We also presented a list of all content words used in the experimental sentences to four first-year interpreting students from a key college in Mainland China and asked them to tick any word which they felt unfamiliar with. The average familiarity was 96.7% for words in asymmetric sentences and 97.4% for words in symmetric sentences, indicating a high and comparable degree of word familiarity between the two types of sentences.

Equipment

The stimuli were presented in black against a light-gray background on an LCD display monitor (1024 X 768 pixels). Subjects' eye movements were recorded using an Eyelink 1000 Plus (SR Research, Canada) eye tracker. The sampling rate adopted was 1000 HZ. The original programs (one for STR in single sentence context, the other for STR in discourse context) were created using *Experiment Builder* 2.1.140, and eye-tracking data was analyzed with *Data Viewer* 3.1.97. All stimuli were displayed in Times New Roman font size 26 with double-line spacing to maximize the chance of linking fixations to specific words.

Procedure

The experiment consisted of two sessions. In the first session, the participants performed sight translation in single sentence context. In the second session, they sight translated in discourse context. The order of the sessions was counterbalanced across participants, and the order of the stimuli (isolated sentences in session 1 and the two texts in session 2) was randomized for each participant. There was a 40-minute break between the sessions. The first session began with a warm-up practice and a 13-point calibration. There were 24 trials during the session: the eight asymmetric sentences and the eight symmetric sentences along with eight fillers were presented in an individually randomized order. The participants were asked to sight translate the sentences appearing on the screen. When the sight translation of one sentence was completed, participants pressed the space bar to continue with the next one. Procedures in the second session were similar: after the warm-up and calibration, participants sight translated the two texts. The same font size and double spacing were adopted for all stimuli. During the experiment, only data for the right eye were recorded. In addition to the eye movements, participants' output was also recorded synchronically.

Data analysis and results

Eye measures and analysis method

This section reports on the cognitive load during STR at sentence and word level. Dwell time and fixation count (FC), the two global measures, were adopted as indicators of overall cognitive load for processing a complete sentence. Here, dwell time includes all fixations and saccades on the experimental sentence, regardless of when they take place. FC refers to the total number of fixations on one sentence. To inform on the cognitive load for the individual words of each experimental sentence, two local eye measures were used, namely first fixation duration and regression path duration. First fixation duration is the duration of the first fixation made upon a word, which indicates early processing (Rayner 1998) and generally reflects lexical access (Rayner 1998; Yan et al. 2013). Regression path duration is the total time of all fixations made on the word and the fixations occurring to the left of that word, namely from the first fixation upon the word to the first fixation to the right of the word (Rayner and Liversedge 2004). It is often taken as the indicator of problem detection, reanalysis, and integration at a later stage (Schaeffer et al. 2016).

Twenty-three students participated in the study, but two quit due to failures in calibration. Eye movement data from 19 participants were used for global analysis, and data from 18 participants were used for local analysis. We assessed eye data quality based on accuracy and stability. Three steps were followed for data trimming:

1. Participants were removed from analysis if half of their fixations were shorter than 200 ms. According to Rayner and Sereno (1994), average fixations during normal reading range between 200 ms and 250 ms, and very frequent short fixations may represent measurement errors.
2. Data cleaning was performed for each participant to eliminate fixations shorter than 80 ms or longer than 1200 ms (White 2008), resulting in removal of 13% of the data.
3. Participants with frequent fixation drift by visual inspection were excluded from the eye movement analysis since their data were not suitable for analysis of word-based processing.

Data were analyzed with linear mixed-effect models in the statistical environment R (R Core Team 2016), using the software package *lme4* (Bates et al. 2015). This method enables analysis of the individual differences between experimental items and participants, variations which are often difficult to detect using more traditional approaches such as ANOVA. The fixed effects include two predictor variables: Complexity (asymmetric and symmetric levels) and Condition (single sentence context and discourse context). To account for between-participant and between-sentence variation, intercepts for Participant and Sentence were added as random effects. *P*-values in the models were estimated using Satterthwaite approximations in the *lmerTest* package (Kuznetsova et al. 2016). Participants' dwell time, fixation count, and regression path duration were logarithmically transformed because of skewed distributions based on visual inspection, but their mean values were reported as non-transformed for ease of interpretation.

Overall cognitive load

Two linear mixed-effect models for dwell time and fixation count were estimated to indicate global processing by using the whole sentence as the unit of analysis. *R*-squared value for the two models were calculated by using the *MuMIn* package (Bartón 2023) to examine the goodness of data fit. Table 1 provides the results of descriptive statistics, and Table 2 presents a summary of the two models. Only main effects are discussed since no statistically significant interaction was found between the fixed terms. The overall model for dwell time ($R^2_{marginal} = .38$, $R^2_{conditional} = .61$). returned a notable effect of word order asymmetry ($t = -3.58$, $p = .001$): considerably longer viewing time was spent on asymmetric sentences than on symmetric sentences in both conditions. The condition effect was statistically significant ($t = -6.67$, $p < .001$) with longer dwell time for sentence processing in single sentence context than in discourse context. Regarding fixation count, the model ($R^2_{marginal} = .17$, $R^2_{conditional} = .58$) demonstrates an asymmetry effect on total fixation count ($t = -4.57$, $p < .001$): asymmetric sentences were fixated more frequently than symmetric sentences. The result also shows a considerable impact of task condition ($t = 3.26$, $p = .003$). Specifically, processing in discourse context elicited significantly more fixations than in single sentence context. Cognitive load, as measured by fixation count, suggests more effortful processing in discourse context whereas analysis of dwell time confirms a cognitive-relieving effect of contextual information. These results suggest that task condition affects the online reading behavior of sight translation.

Table 1. Mean (SD) values of eye measures for overall cognitive load

	Asymmetric sentences	Symmetric sentences
Dwell time (ms)		
Single sentence context	18,352 (3,677)	15,332 (2,760)
Discourse context	14,828 (3,174)	11,720 (2,925)
Fixation counts		
Single sentence context	50 (14)	42 (10)
Discourse context	59 (12)	46 (14)

Table 2. Linear mixed effects models using treatment coding for the factor 'asymmetric-sentence condition' as the reference level (significant p-values at the level of $p < .05$ are marked with *)

Measure	Effect	Estimate	Standard error	*t*-value	*p*
Dwell time	Asymmetry	−0.09	0.03	−3.58	.001 *
	Condition	−0.11	0.02	−6.67	<.001 *
	Asymmetry x condition	−0.03	0.03	−0.86	.39
Fixation count	Asymmetry	−0.08	0.02	−4.57	<.001 *
	Condition	0.05	0.02	3.26	.003 *
	Asymmetry x condition	−0.03	0.03	−1.00	.32

Local cognitive load

To avoid spillover effect in context, local measures of words at the first and final positions of all experimental sentences were not calculated. Two linear mixed-effect models were estimated for first fixation count and regression path duration to observe word-level processing. The results of descriptive statistics appear in Table 3, and the fixed effects of the model are summarized in Table 4.

Results of the model for first fixation duration ($R^2_{marginal} = .06$, $R^2_{conditional} = .35$) demonstrated a significant effect of asymmetry ($t = -4.37$, $p < .001$), with word processing in asymmetric sentences triggering longer first fixation duration. This result suggests that the asymmetry effect was detectable even at the early processing stage dominated by lexical meaning retrieval. For the model for regression path duration ($R^2_{marginal} = .18$, $R^2_{conditional} = .21$), the asymmetry effect was also statistically significant ($t = -3.38$, $p = .002$): asymmetric sentences elicited longer regression path duration than symmetric sentences did. There was also a statistically significant effect of condition ($t = 3.9$, $p < .001$): regression path duration was longer in discourse context than in single sentence context.

Table 3. Mean (SD) values of word-based eye measures for local cognitive load

	Asymmetric sentences	Symmetric sentences
First fixation duration (ms)		
Single sentence context	208 (30)	197 (30)
Discourse context	217 (33)	198 (31)
Regression path duration (ms)		
Single sentence context	605 (173)	534 (163)
Discourse context	789 (200)	606 (207)

Table 4. Linear mixed effects models using treatment coding for the factor 'asymmetric-sentence condition' as the reference level (significant *p*-values at the level of $p < .05$ are marked with *)

Measure	Effect	Estimate	Standard error	*t*-value	*p*
First fixation duration	Asymmetry	−14.85	3.4	−4.37	< .001 *
	Condition	5.29	3.27	1.62	.11
	Asymmetry x condition	−7.56	6.4	−1.18	.25
Regression path duration	Asymmetry	−0.09	0.03	−3.38	.002*
	Condition	0.08	0.02	3.9	< .001 *
	Asymmetry x condition	−0.07	0.04	−1.59	.12

Strategy preference for processing word order asymmetry

Setton (1999) proposed four main strategies for interpreting language-pair specific structures, namely waiting, stalling, chunking, and anticipation. According to whether the original word orders of the asymmetric structure are changed by interpreters, strategies for structural differences can be divided into two major types: segmentation and restructuring (Guo 2011). Segmentation, also known as chunking, is a coping tactic that divides original sentence sequentially into several shorter segments (Ahrens 2017; Jones 2014). By restructuring, interpreters change the original word order (Donato 2003), for example, by putting the source RC before the relative pronoun in the TL when translating from English to Chinese.

To explore which strategy was used more frequently, the production of asymmetric sentences was transcribed and analyzed. The recordings showed that few participants changed strategy during on-line processing. For example, one participant attempted to reorder the original RC sentence but soon gave up and ultimately applied chunking. Here, the strategy labeling was based upon the final production. The observed gap in overall frequency was greater in discourse context. To examine whether preference of strategy is related to amount of contextual information, we fitted a generalized mixed effects model for the choice of strategy as the binary dependent variable. The predictor was Condition (single sentence context vs discourse context), and two random effects were Participant and Sentence. Although more sentences were segmented in the discourse condition, the impact of the task condition on the use of strategy for the asymmetric sentences was not statistically significant ($z = -1.05$; $p = .31$).

Table 5. Frequencies of segmentation (S) and restructuring (R) in the two task conditions

	Single sentence context	**Discourse context**
Segmentation	113	127
Restructuring	39	25

Among the 19 participants, one participant (P10) chunked all asymmetric sentences across both conditions. 11 participants adopted segmentation more frequently in discourse condition than in single sentence condition, with eight chunking all the asymmetric sentences in discourse condition. Four participants chunked an equal number of asymmetric sentences in both conditions. Only three participants employed restructuring more frequently than segmentation in single sentence condition. More than half of the participants increased their use of segmentation when sight translating in wider contexts, suggesting an impact of task condition on their strategy choice. However, given the marginal between-condition differences, this result needs to be further validated by larger sample and more observations in similar interpreting tasks.

Discussion

Effect of word order asymmetry on the cognitive process of sight translation

This study addresses word order asymmetry in the scenario of English–Chinese sight translation from a cognitive perspective. The primary questions under discussion are how and to what extent on-line processing is affected by word order asymmetry.

Cognitive processing disrupted by word order asymmetry

The first research question examines the impact of word order asymmetry on the cognitive process. The results support a considerable overall impact of word order asymmetry on the process of English–Chinese sight translation: differences in word orders resulted in considerably greater cognitive load in terms of dwell time and fixation counts, which provides evidence for what has been shown in product-oriented studies (Wang and Gu 2016). Although the participants had been trained systematically and had access to more contextual support in the discourse context, they were nevertheless largely unable to free themselves from surface structure constraints.

The impact of asymmetry can be interpreted from the perspective of structural priming. Priming refers to the tendency to reuse a similar structural pattern that has been previously comprehended or produced (Bock 1986; Bock et al. 2007; Schaeffer et al. 2017). A substantial body of studies has demonstrated that priming exists between languages, and the effect is similar with within-language priming (e.g., Kantola and Van Gompel 2011; Schoonbaert et al. 2007). In a cross-linguistic task such as translation, how much source item and target item share structural representations determines the strength of the priming effect (Schaeffer et al. 2016). When participants interpreted symmetric sentences that syntactically overlap with the TL, the co-activated structural representations would facilitate on-line comprehension and parsing. This structural priming allows for a syntactically linear translation, which accounts for less cognitive load for the symmetric sentences. However, the benefit of priming disappeared during the processing of the asymmetric sentences. When the primed structure was incompatible with target norms, the participants had to try to inhibit the tendency to be primed and to resist the stronger SL interference in STR due to the visual accessibility of source texts. These factors combined may contribute to an increase in cognitive load.

In addition to global processing, local processing at word level was also affected. To reflect processing through different stages, eye indices were divided into one early measure (first fixation duration) and one late measure (regression path duration; Clifton, Staub, and Rayner 2007). Generally, first fixation duration is associated with early-stage processing such as word retrieval and comprehension (Rayner 1998). No significant differences between the asymmetric and symmetric sentences was expected to emerge during this stage because the two types of sentence were matched in word frequency and word length, implying a similar cognitive load for word meaning retrieval. However, data analysis showed that first fixation duration for words in asymmetric sentences was significantly longer than for words in the symmetric sentences, indicating greater efforts in the participants' first contact with the source word. Therefore, it appears that participants embarked on additional processing during this stage. This strong asymmetry effect on first fixation duration suggests the activation of syntactic aspects of the target language. Both lexical and syntactic knowledge were activated during the first fixation, and incongruent word orders required longer time for structural analysis or anticipation. Analysis of first fixation duration indicates that the effect of word order asymmetry exerted strong influences during the initial stages of reading.

The asymmetry effect for regression path duration, which is the later-stage eye measure, is highly significant. According to Levy (2008), the difficulty of syntactic processing is related to the degree to which the initially anticipated structures accord with the actual sentence structures. During sight translation, the target expressions or the expectations for the upcoming structures were constructed incrementally. When the two languages had parallel syntactic structures, parsing was facilitated with little or no need for reprocessing. However, the initial expectations were more likely to be violated by the asymmetric structures that did not conform to the syntactic rules of the TL. For example, English RCs tend to be more unexpected in the eyes of native Chinese speaker. Therefore, it was possible that when the participants noticed that their initial anticipation was incorrect, they had to revisit the word and sometimes the regions to the left for syntactic reanalysis and repair. This expectation violation and correction process contributed to a significant increase in the values of the late eye measures. Additionally, the need for establishing syntactic links between segments or syntactically incorporating incoming parts into the earlier words may also increase later-stage processing effort.

Limited role of context in offsetting asymmetry-induced cognitive load

The first research question addresses the role of contextual information in processing word order asymmetry. It is assumed that wider contexts alleviate cognitive load and modulate asymmetry-induced disruption. The results suggest an inconsistent function of context during STR: a larger amount of contextual information contributed to a more time-efficient global processing, as measured by significantly shorter dwell time under discourse condition. Discourse context helped reduce total processing time since contexts improved word predictability and some words can thus be skipped. However, this contextual benefit in terms of total time ran contrary to the data on fixation count and regression path duration. When compared with STR in single sentence context, STR in discourses consumed shorter total time but involved significantly more fixations, indicating an effortful reading pattern. Participants had to shift their attention more quickly and frequently between words and lines within a shorter period. In this sense, contextual information did not necessarily reduce cognitive load.

Several factors may explain this unexpected result. First, it may be related to an extra updating cost in wider contexts. A precondition for text comprehension is the establishment of a coherent mental model (Kintsch 2004) that is constructed by constantly updating the current model built on earlier words (Van den Broek et al. 1999). Here, when more contextual information was accumulated as the task progressed, participants had to update or revise the previous mental model with frequent rereading and reanalysis. Second, this phenomenon may be accounted for by stronger visual interference in discourse. According to Agrifoglio (2004), visual interference in STR was induced by the constant presence of textual information. Shreve et al. (2011) found that during STR, all second paragraphs were apparently more effortful than the first paragraphs to process, suggesting the incremental cognitive load in discourse context. Efforts due to visual interference seemed to increase as the discourse unfolded. Last, more fixations in discourse context may be attributed to frequent on-line searches for contextual cues for semantic or syntactic integration. Readers tend to make use of earlier textual information to direct eye movements when processing a new or difficult message (e.g., Ito et al. 2018). Therefore, the participants were more likely to reread the prior sections when asymmetric structures appeared.

Segmentation as the primary strategy adopted in cases of word order asymmetry

The second research question focuses on response to asymmetric structures. The results demonstrated that segmentation was used far more frequently than restructuring under both conditions. In addition, the participants segmented more sentences in discourse context, which corroborated the findings on cognitive load, namely that STR in discourse context generated greater efforts. STR in wider contexts involved greater memory load and stronger visual interference, which constrained the already insufficient processing capacity. Therefore, segmentation under this circumstance was relied upon to ease the memory burden and to avoid saturation of cognitive resources.

The higher frequency of segmentation can be accounted for by both the need for relieving cognitive burden and the norm based on training and professional experience. Shlesinger (2003) points out that norm-driven strategies may play a more important role in shaping interpreters' on-line decision making than was assumed. Wang and Gu (2016) listed four major factors that influenced interpreting performance, namely interpreting competence, cognitive conditions, norms of interpreting, and language-pair specificity. Norms can be understood as the common rules or expectations accepted by a certain community (Toury 2012). In this study, the norms of interpreting include the shared views on "what the generally accepted interpreting methods and strategies are" (Wang 2012, 199). As an effective coping tactic to deal with language-specific difficulties, segmentation has been widely taught in interpreting curriculums and recommended by instructors (e.g., Qin and He 2009; Wan 2005).

Mental workings of sight translation and implications for interpreter training

The findings generated from the first and second research questions enrich understanding of the mental mechanisms involved in interpreting and yield suggestions for future interpreter training. First, the analysis of eye movement offers glimpse into the mental workings of STR by exploring two opposing approaches to translation, namely the sequential/vertical approach and the parallel/horizontal approach (de Groot and Christoffels 2007: 26). The sequential view holds that translation is a concept-driven process during which the SL is first abstracted into non-linguistic concepts and then reorganized in the TL (Schaeffer and Carl 2013). It is related to the meaning-based approach advocated by the Paris School. In contrast, the parallel view holds that SL comprehension and TL production occur simultaneously: source and target linguistic systems are co-activated during translation (Schaeffer and Carl 2013). In the present study, an early effect of word order asymmetry indicated that processing during STR was also parallel since syntactic aspects of the TL appeared to be anticipated during the initial reading of source words. When other linguistic properties such as word frequency, word length, and familiarity were matched, no significant differences would emerge since the initial processing of words in asymmetric and symmetric sentences only involves lexical processing. The longer first fixation duration during interpretation of asymmetric sentences suggested additional activities such as syntactic anticipation and planning, and greater mental load was imposed by word order divergence.

However, the results need be interpreted with caution since differences in early eye measures may also be caused by inherent structural difficulties in the asymmetric sentences. To distinguish normal reading from cross-linguistic transfer, Balling et al. (2014) investigated word order effect (both canonical SV order and non-canonical VS order in the SL) on Danish–English translation. They found that the gaze time on incongruent VS segments in the source text was significantly longer than for congruent SV segments. To rule out the possibility that this effect was caused by the inherent difficulty of the VS segment, the same source texts were also used for both L1 and L2 reading tasks. A group of native Danish speakers and native English speakers who had acquired a high proficiency in Danish read the source materials for comprehension. No significant effect of congruence was observed during either of the reading tasks. The absence of word order effect in the reading tasks suggested that the congruence effect in translation was not a result of the VS segments being inherently more difficult but was rather due to the activation of target syntactic structure during SL comprehension. Therefore, the asymmetry effect on first fixation duration in the current study may be evidence of parallel processing during interpreting. However, this speculative inference requires confirmation through the introduction of additional baseline tasks in future studies.

Second, the study highlights the importance of improving students' awareness of structural difficulty and segmentation proficiency Although sense-based interpretation is highly valued in pedagogical settings and *deverbalization* has been widely taught as a method for coping with language-specific difficulties, participants still experienced difficulties in overcoming structural asymmetry as evidenced by both the on-line and off-line data. Therefore, it is of practical importance to develop students' awareness of structural asymmetry between SL and TL. Being aware of and prepared for structural differences is not contradictory with a sense-based approach. Instead, these approaches complement each other: a meaning-oriented approach facilitates on-line comprehension, which provides a foundation for successfully use of language-pair specific strategies. Meanwhile, students with deeper syntactic knowledge can quickly identify the primary and secondary information to aid in more efficient delivery. Previous studies have revealed an impact of syntactic structures on information status (Tyler and Davies 1990). Certain syntactic cues work to structure the discourse, signal the logical relations, and mark the emphasized propositional content (Tyler 1994).

The provision of greater levels of contextual information was anticipated to decrease asymmetry-induced efforts. However, the results indicate that wider context does not necessarily reduce cognitive load. Processing in discourse context resulted in more frequent fixations and more integration difficulties. Single sentences may serve as materials for practice at preliminary training stage to familiarize students with basic strategies and techniques. As training progresses, however, more attention should be devoted to long and coherent texts in authentic settings to better prepare trainees for the greater contextual constraints typical of real working conditions.

Conclusion

This study confirms the negative impact of word order asymmetry in English–Chinese sight translation. First, the cognitive process of sight translation was influenced by word order asymmetry, corroborating the results of previous product-oriented studies. This asymmetry effect may take place during the initial processing. Second, the role of context was limited in offsetting the asymmetry effect. Although overall processing was faster in wider contexts, more contextual information did not make the processing less effortful. Third, segmentation was the primary strategy used by most participants to relieve the cognitive load due to word order asymmetry. Instead, restructuring may involve greater efforts in coordinating the memory storage and syntactic integration. When more cognitive pressures were imposed in the discourse condition, some participants increased their use of segmentation to avoid cognitive overload.

The study examines the effect of word order asymmetry by focusing on cognitive load, the core concept in cognitive studies of interpreting. By measuring the asymmetry effect by eye tracking, this study enriches understanding of the relationship between linguistic properties and cognitive load during interpreting. From the perspective of sentence processing, this study creates the possibility of investigating syntactic processing in a code-switching condition, presenting an opportunity to see whether previous psycholinguistic theories (such as priming) concerning sentence processing apply to interpreting.

The study has several limitations. First, the study was conducted on a small pool of participants in an artificially controlled environment. For example, the forehead part of the chin rest during the sight translation was used for improving data stability and accuracy, but it may run contrary to the long-held suggestion that naturalistic recording and unobtrusive measurement are always favored in empirical studies of interpreting. More efforts are required to better handle the tradeoffs between ecological validity and experimental control (Mellinger & Hanson 2022). Instead of pursuing the most realistic settings, the concern for ecological validity should be balanced with the research purpose, theoretical framework, and variable operationalization. Second, in terms of model fitness and effect sizes as measured by R^2, the fixed effects on the response variables were not as strong as expected, suggesting large between-participant variations and some potential factors that were not examined in the current study, for example, the position of the experimental sentences on the screen. Finally, the study involved only interpreting trainees without comparisons between experts and novices.

It is expected that in future studies, a more robust experimental design with the participation of professional interpreters will be adopted. In settings closer to real-life interpreting, it would be interesting to see if the results could be generalized to other language pairs. Furthermore, a holistic view of the asymmetry effect on cognitive processing in interpreting calls for triangulation from eye-tracking experiments and off-line analysis such as product analysis, survey, and interviews in order to better capture the multi-dimensional features of interpreting.

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