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A cognitive investigation of 'chunking' and 'reordering' for coping with word-order asymmetry in English-to-Chinese sight translation: Evidence from an eye-tracking study

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Abstract:

Word-order asymmetry between source language and target language has been recognized as a major obstacle in interpreting. Regarding whether the original word order is changed in target production, two strategies for asymmetrical structures are identified: chunking and reordering. This study primarily examined the cognitive mechanism involved in applying these two strategies during English to Chinese sight translation. The cognitive load associated with chunking and reordering was measured by eye movement and the resulting data were analysed. A group of interpreting trainees sight-translated asymmetrical sentences in two contexts: sentence and text. Their eye-movement measures, including total dwell time, fixation count and rereading rate, were recorded. The results demonstrate that chunking was the primary strategy used to render word-order asymmetry in both task conditions. A greater cognitive load was found in the reordered sentences. More contextual information did not contribute to an execution of the strategies that required less effort. This research is one of the first attempts to explore the cognitive process associated with interpreting strategies for word-order asymmetry. It provides a new perspective with which to deepen our understanding of the cognitive mechanism underlying the use of a strategy.

Keywords: word-order asymmetry, sight translation, eye-tracking, chunking, reordering

1. Introduction

1.1 Word-order asymmetry as a significant challenge in English – Chinese interpreting

The effect of "language specificity" (Gile 2011a: 182) is an extensively debated topic in interpreting studies. Language specificity refers generally to languagespecific factors such as the varying degree of syntactic asymmetries between a source language (SL) and a target language (TL) (Seeber 2011). The divergence of surface structures – notably word order – has been widely considered as a prominent obstacle in simultaneous interpreting (SI) (e.g., Donato 2003; Gile 2005; Setton 1999). Models which emphasize the constrained processing capacities in SI assume some links between input structures and performance (see Gerver 1976; Gile 1995; Moser-Mercer 1976). Contrasting word order is believed to induce more interpreting errors, cause more problems in coordination and trigger cognitive overload (e.g., Gile 2005). An increasing amount of evidence from studies of different language pairs has supported the negative impact that wordorder asymmetry has on interpreting performance, as evidenced by more errors and disfluencies (Gile 2011b; Wang & Gu 2016), coherence damage (Ahn 2005), delivery speed (Lee 2012; Seeber 2001) and greater pupil dilation (Seeber & Kerzel 2011). In the present study, the notion 'word-order asymmetry' is adopted to describe the differences in syntactic order between the SL and the TL during interpreting.

One of the language combinations in interpreting that merits special attention is English – Chinese (E–C). English and Chinese are typologically different languages at the lexical, syntactical and discourse levels (Li & Thompson 1981). These salient differences cause additional difficulties in interpreting, a finding that has been supported by an array of empirical studies through online measurement (e.g., Ma 2019) and the analysis of target outputs (e.g., Dawrant 1996; Wang & Gu 2016).

The present study focuses on two structures that are most representative of word-order asymmetry in E–C interpreting, namely, relative clauses (RC) and passive constructions (PC). Regarding the correlations between head nouns and modifiers, English and Chinese conform to divergent branching directions. Whereas English RCs always follow head nouns as a post-modifier, a whole 'participial' RC in Chinese may precede and modify a noun (Setton 1999). Therefore, additional efforts may be required, especially when a back-loaded English RC is rendered as a front-loaded structure in Chinese. This reordering may become more difficult when the original RCs are embedded in long, complex inner struc tures (Shlesinger 2003; Wang & Gu 2016) such as: 'We must defeat these terrorists, these monsters who killed or enslaved innocent people, to rebuild peace and stability.'

Passive construction poses another potential problem in E–C interpreting. The major difference between English PCs and Chinese PCs lies in the correlations between passive verbs and agents. In

English, an agent is always located behind a passive verb (Xiao et al. 2006), whereas in Chinese an agent always precedes a passive verb (Chappell & Shi 2016). Therefore, when an English PC is rendered into a well-formed Chinese sentence, additional difficulty may arise as a result of agent relocation.

1.2 Coping with word-order asymmetry in English – Chinese (E–C) interpreting

In order to resolve the potential management problem with processing resources caused by word-order asymmetry, specific interpreting strategies are required. Strategies in SI have been categorized and approached from different perspectives according to processing stages, task modes, directionality and language-pair specificity (see Bartłomiejczyk 2006; Donato 2003; Li 2015). Strategies for handling structural differences in interpreting are categorized as language-pair specific, these being affected by the degree of similarity between the SL and the TL (see Li 2015).

If the language pair is syntactically divergent, as in interpreting between subject-verb-object (SVO) and subject-object-verb (SOV) languages such as English and German, interpreters are likely to be confronted with a dilemma between time-lag control and memory-resource management (Christoffels et al. 2006). They can wait until the whole structure or sentence is completed for better syntactic analysis and planning; however, the waiting entails higher risks of cognitive saturation and errors since larger segments need be stored in short-term memory before syntactic integration can occur (Christoffels et al. 2006; Riccardi 1998).

A handful of empirical studies have been conducted on the relationship between word-order or syntactic differences and the use of strategies in E–C interpreting. One dominant approach is to investigate the categories, frequencies, and distribution of certain strategies in response to language-pair specificity. An early exploration was carried out by Dawrant (1996), who investigated the strategies used by professional interpreters during Chinese – English (C–E) SI. The analysis demonstrated that when Chinese-specific structures such as the DE-structure[1] and a locative phrase

[1] The DE structure in Chinese is one in which a noun phrase (NP) is preceded by a modifying phrase. The particle 的 de0 'DE' is used as a marker of modification that links the NP and the modifying phrase (Li & Thompson 1981). In the following example, the clause '以前住在上海 (used to live in Shanghai)' modifies '日本人 (Japanese people)'.
Example
以前住在上海 的 日本人
Before live in Shanghai DE Japanese people. (Japanese people who used to live in Shanghai.)

occurred in the source speech, the interpreters were more likely to encounter problems. They had to render these structures by anticipating what would come next or by following the original word order to reduce cognitive load. More recently, Guo (2011) examined interpreters' performance of E–C SI in both directions and found that in C–E SI, 75% of Chinese front-loaded sentences were restructured into English back-loaded sentences. Wang and Zou (2018) examined how, during C–E consecutive interpreting (CI), professional interpreters rendered attributive modifying Chinese structures, which are always placed before head nouns, into English, a typical back-loaded language. Based on the parallel corpus of Chinese – English Interpreting for Premier Press Conferences (CEIPPC), they found that most pre-loaded modifying structures in Chinese were interpreted into back-loaded structures or a mixture of frontand back-loaded structures in English. In addition, they analysed the text difficulty and reading ease between the interpreted English of CETPPC and the original English from a comparable corpus. The comparison demonstrated that the interpreted discourse contained more long and complex sentences, suggesting that extra effort was required during interpreting. According to Wang and Zou (2018), this might be attributed to the frequent use of reordering in order to render the asymmetrical structures.

The studies above highlight the importance of strategies that are languagepair specific in handling word-order asymmetry. This in turn implies that strategy choice has an effect on the cognitive load involved. 'Cognitive load' has been used as the conceptual basis for exploring the cognitive operation of interpreting (see Chen 2017; Seeber 2011). As emphasized by Gile's Tightrope Hypothesis (1999), interpreters work close to saturation point in terms of cognitive load. What is worse, specific task characteristics (e.g., language combinations and interpreting direction) and environmental characteristics (e.g., a lack of preparation) may constrain the cognitive resources available to the interpreters further and increase their cognitive load (Chen 2017).

1.3 Cognitive load associated with the strategy for coping with word-order asymmetry

We identify two major approaches to managing structural asymmetry, namely, chunking and reordering, depending on whether the source word order is changed during the production of the TT.

Chunking, sometimes known as "linearity" or the "salami technique" (Ilg 1978; Setton 1999), refers to the process by which interpreters divide an original sentence into several shorter segments and reformulate them sequentially (Ahrens 2017; Kader & Seubert 2014). Chunking is especially useful when dealing with long, complex sentences (Garzone 2002). It can save interpreters' processing capacity requirements for memory (Gile 2011a), therefore freeing up more cognitive resources for other operations such as comprehension and reformulation (Gile 2002). Successful chunking is driven by the unit of meaning: the smallest unit that triggers a meaning representation (Jones 2014). A meaning unit in interpreting can be as short as a word but no longer than a sentence, depending on a range of factors, such as syntactic profiles (Davidson 1992) and the interpreter's working memory capacity (Miller 1956).

Another way of managing word-order asymmetry, apart from chunking, is reordering (Wilss 1978). By reordering, interpreters change the original ST word order. For example, to interpret English back-loaded structures into Chinese, interpreters need to change the order of the post-modifiers to come up with a front-loaded structure that adheres to the grammatical rules of Chinese. Example (1) illustrates the ways in which a sentence with a relative clause can be chunked and reordered, respectively, in E–C interpreting.

Example 1.	Source speech	(RC is underlined) *Addressing the migration crisis is an enormous challenge which all European countries should face up to and work hard to resolve*.
	Target speech 1	解决移民危机是一项巨大的挑战，所有欧洲国家都应面对并努力应对这项挑战。 (*Addressing the migration crisis is an enormous challenge, all European countries should face up to and work hard to resolve this challenge.*)
	Target speech 2	解决移民危机是一项所有欧洲国家都应面对并努力应对的巨大挑战。 *(Addressing the migration crisis is all European countries should face up to and work hard to resolve DE enormous challenge.)*

As shown in the example, both strategies can be applied to help interpreters cope with RCs, a syntactically asymmetrical construction in E–C interpreting. In the case of chunking (Target speech 1), the whole sentence is divided into two separate clauses with 'which' as the cutting point. The location of the interpreted RC remains unchanged in the target sentence. In reordering, by contrast, the backloaded English RC is relocated before the head noun (Target speech 2).

It has been recognized that, compared to chunking, reordering would be more effortful and would overburden the interpreters' short-term memory (Wan 2005). This cognitively taxing effect of reordering echoes some scholars' recommendations of chunking as an effective strategy to cope with word-order asymmetry in E–C interpreting (e.g., Zhong 1984). However, these claims are made primarily from a didactic perspective; only a few are made based on empirical evidence. For example, Meuleman and Van Besien (2009) studied the strategy used by simultaneous interpreters when they dealt with syntactic complexity and high delivery speeds. It was found that most of the interpreters preferred segmentation in order to achieve an acceptable translation, which seems to support the literature in that interpreters are advised to slice the long and complex sentences into shorter segments. However, with a lack of evidence from real-time processing, it cannot be readily concluded that chunking is cognitively less demanding since the eased memory burden may come at the cost of reformulation difficulties. In fact, during this reformulation process, the interpreters are expected to connect the chunking units to explicate the original logical links (e.g., Setton 1999). This might increase their production effort, a process that does not necessarily make chunking easier than reordering.

Questions pertaining to which strategy is cognitively more efficient, and whether any link can be found between the strategy choice and processing efforts, remain under-explored. By measuring and analyzing the cognitive processing associated with chunking and reordering, we may obtain evidence to support the wide use of chunking in interpreter training.

In addition to the cognitive load consideration, the preference for chunking or reordering can also be modulated by a variety of factors such as interpreting expertise and contexts. For instance, a greater amount of contextual information may alleviate the asymmetry-induced effect. Previous research on reading has demonstrated a contextual benefit for word recognition and prediction (e.g., Rayner 1998). Words are recognized more quickly when preceded by a related word or sentence than when they are processed in isolation or in a neutral sentence (Fischler & Bloom 1985). Contexts with strong semantic association speed up reading by integrating the current word into readers' pre-activating concepts, relations and schemas (Schustack et al 1987; Setton 1999: 97). Considering these contextual benefits, we assume that interpreters with access to more contextual information will be less vulnerable to asymmetry disruption and cognitive overload, which might have an impact on their strategy preference.

1.4 Exploring cognitive processing in sight translation using eye-tracking

Sight translation (STR) refers to the oral translation of a written text. It seems to have more in common with SI, since concurrent comprehension and production is required in both SI and STR. Therefore, sight translation has been considered as a special variant of interpreting (Pöchhacker 2016). However, in STR, interpreters might be constrained by SL interference to a greater degree, owing to the constant visual presence of source information (Agrifoglio 2004). In a recent eye-tracking study, Chmiel and Lijewska (2019) investigated syntactic processing in STR by professional and novice interpreters. Th participants sight-translated both subject-relative clauses and object-relative clauses from English to Polish. An analysis of their eye movements demonstrated that the structurally more difficult object-relative clauses were viewed for significantly shorter lengths of time than were subjective-relative ones. This was attributed to the interpreters' tendency to avoid textual interference in order to reduce the coordination effort. The results suggest that interpreters in STR are constrained by interference from the written text and this visual interference may impose additional burdens on their ability to coordinate between reading and oral production.

In this study, we adopt eye-tracking to explore the cognitive processing related to chunking and reordering when student interpreters are engaged in STR from English to Chinese. Based on the assumption that 'there is no appreciable lack between what is being fixated and what is being processed' (Just & Carpenter 1980: 331), eye-tracking technology allows for a moment-to-moment recording of the cognitive processing in language tasks such as reading, writing and translation (Hvelplund 2017; Seeber 2013). The investigation of cognitive processing in this study includes two dimensions: the cognitive load involved in the use of strategy in terms of eye-movement measures and the real-time reading behaviors associated with the strategies as indicated by rereading rate and fixation sequence (also known as 'gaze path').

Eye movements can be quantified via a variety of eye-movement measures such as fixation duration, fixation count (FC), pupil size and regression count (Hvelplund 2014; Saldanha & O'Brien 2013). Through these measures, cognitive load, which used to be a theoretical construct, can now be translated into observable and measurable parameters (Chen 2017). They can then be used to infer the cognitive load in reading, writing and translation (O'Brien 2009; Saldanha & O'Brien 2013). For example, longer and more frequent fixation durations are associated with processing that requires more effort, often indicating increased task difficulty and greater cognitive load (Hvelplund 2014; O'Brien 2009). Therefore, by measuring the eye movements of the participants when handling the asymmetrical structures, we can identify which strategy is cognitively more taxing.

In addition, eye-tracking data can be visualized through heat maps, gaze plots and scan paths to provide a general view of real-time reading behavior during language tasks, such as attention shifts (Hvelplund 2011), re-analysis (Clifton et al. 2007; Rayner 2009), attention resource allocation and the intensity of cognitive processing in STR (Dragsted & Hansen 2009). Based on the fixation sequence for the asymmetrical sentences, we can observe the reading mechanism related to the use of strategy, such as identifying the strategy that results in less frequent rereading and a smoother reading pattern.

1.5 Research questions

This study aimed to examine the ways in which word-order asymmetry in E–C STR is managed and the effect of the strategy used on cognitive processing. Eye-tracking was used to explore whether or not the two strategies for coping with asymmetrical structures (chunking and reordering) are associated with eyemovement data including dwell time (DT), FCs and rereading rate, and if so, how. In addition, gaze plots were used to give a straightforward view of online processing when the strategies were applied. By investigating the effects of chunking or reordering on participants' real-time processing, we sought to identify whether a syntactically linear approach (i.e., chunking) is cognitively more efficient in terms of cognitive load and reading behavior.

We attempted to answer the following research questions (RQs):

- RQ1: How do interpreter trainees deal with word-order asymmetry in E–C STR as indicated by the frequency and distribution of the strategies they adopt? Does the amount of contextual information affect their strategy preference?
- RQ2: How does strategy preference affect the cognitive processing of interpreter trainees when they deal with word-order asymmetry? What is the role of contextual information in modulating the cognitive load involved in the use of strategies?
    a. With regard to cognitive load, does chunking or reordering consume more cognitive resources?
    b. Are there any differences in real-time reading behavior between chunking and reordering?
    c. Does strategy use in the text context induce a greater cognitive load than

in the sentence context?

2. Methodology

The design of this study draws upon that of a larger project (Ma 2019) which examined the effect of word-order asymmetry on the cognitive process in E–C STR. The primary data source for this article are the eye-movement data associated with the use of strategies by the learner interpreters in processing asymmetrical sentences.

2.1 Participants

A total of 23 postgraduates (mean age: 23 years, *SD*: 1.16 years, range: 21–25 years) enrolled in a translation and interpreting MA program in a college in Hong Kong participated in the project. They had similar language backgrounds (Chinese L1, English L2) and had completed at least 12 weeks of intensive training in interpreting. In order to ensure that they had all acquired a high level of proficiency in English, only those who scored 6.5 or higher on the International English Language Testing System (IELTS) examination were invited to participate. According to the background questionnaires, all the students qualified to participate in the experiment. In addition, the participants were required to self-assess their proficiency in L2 reading and speaking, the two critical components of STR. The proficiency scale ranges from 1 to 10 (1: not proficient; 10: highly proficient). The results demonstrated that the participants were highly proficient in L2 reading (M = 8.23, SD = 0.45) and were fluent L2 speakers (M = 7.6, SD = 0.9). All of the participants had normal or corrected-to-normal vision.

2.2 Design and materials

Two types of experimental sentences in English (SL) were adopted for the STR task: asymmetrical sentences and symmetrical sentences. Each asymmetrical sentence contained one RC or PC structure, the rendition of which might require a change of word order to comply with Chinese (TL) grammatical rules. Each symmetrical sentence was syntactically similar to Chinese and could be interpreted by following the original English structure. The participants processed the sentences in two task conditions: a sentence condition (sentence context) and a text condition (text context). In the sentence condition, the sentences were presented in isolation and were interpreted individually.

In the text condition, the sentences were embedded in two flowing discourses that contained the experimental sentences. The essential difference between the two task conditions was the amount of contextual information available.

A total of 16 experimental sentences were employed for the sentence condition. Eight were asymmetrical (four containing RCs and four containing PCs) and the remaining eight were symmetrical. All the sentences were adapted from English speeches given at authentic interpreting settings and were on topics familiar to the participants. In the text condition, two STs of similar length, initially written for oral delivery (see Appendix A), were chosen. Each text contained four asymmetrical sentences (two RCs and two PCs) and four symmetrical sentences (two RCs and two PCs). In order to meet the stimuli criteria, we reformulated some sentences to change their syntactic structures while retaining their semantic meaning. Every two experimental sentences were separated by one filler sentence to avoid a spill-over effect. Four interpreting teachers from a Hong Kong university assessed the coherence of the adapted STs by individually reading and assessing the two texts respectively on a five-point scale (1: very low coherence; 5: very high coherence). The average level of coherence was 4.7 for Text A and 5 for Text B with an inter-rater agreement of 68% among the four teachers. This indicated that the adaptation did not affect the textual coherence very much.

The asymmetrical and symmetrical sentences were matched across conditions according to sentence length (21 words), word length (the number of letters in each word) and word frequency. The statistical tests showed that the mean word length of the asymmetrical sentences (M = 4.97, SD = 0.15) was similar to that of the symmetrical ones (M=5.03, SD=0.25, t (30)=0.5, p=0.62). Linguistic profiling of the experimental sentences was conducted in *Vocabprofile* (Cobb 2002). It showed that 81.85% of the words in the asymmetrical sentences and 80.5% of the words in the symmetrical sentences were ranked within the 1,000and 2,000word frequency bands in English. In addition, we asked four first-year interpreting students from a college in mainland China to identify any unfamiliar word in a list of all the content words used in the experimental sentences. The average level of familiarity was 96.7% for words in the asymmetrical sentences and 97.4% for words in the symmetrical sentences; this indicated a high and comparable degree of word familiarity between the two types of sentence.

2.3 Apparatus

All the source materials were presented in black against a light-gray background on an LCD display monitor (1,024 × 768 pixels). The same font size (Times New Roman 26) and double spacing were adopted for all the stimuli. Eye movements were recorded by an Eyelink 1000 Plus eye-tracker, with a sampling rate of 1,000 Hz. The original eye-tracking program was created using Experiment Builder 2.1.140 and the eye-tracking data were analyzed using Data Viewer 3.1.97.

During the experiment, a forehead rest was used to avoid the impact of head or body movement on recording and to improve data accuracy.

2.4 Procedure

The participants were tested individually. The experiment consisted of two sessions. The first session began with a warm-up task and a 13-point calibration. A total of 24 trials with eight asymmetrical sentences, eight symmetrical sentences and eight filler sentences were presented in random order. The participants sighttranslated the sentences appearing on the screen and pressed the space bar immediately after a sentence was completed in order to proceed to the next one. In the second session, the participants sight-translated the two texts after a warm-up and calibration, with the order of texts alternating for each participant. Only data for the right eye were recorded and the participants' eye movements and output were recorded synchronically. The order of the two sessions was randomized across the participants. The participants were given a 40-minute break between sessions.

3. Results

This section reports on the eye-movement data that reflect the cognitive processing associated with chunking and reordering. During the experiment, two participants withdrew as a result of failures in calibration. We then examined and filtered the data according to the following criteria:

- – Participants were excluded from the analysis if half of their fixations were shorter than 200 ms, since very frequent short fixations may reflect errors or instability during data recording.
- – As for the remaining participants, fixations shorter than 80 ms or longer than 1,200 ms were removed (White 2008).
- – In addition, participants with significant fixation drifts were also excluded from

the analysis.

After the data examination, the data from 19 participants were used for the analysis of cognitive load.

3.1 Frequencies and distribution of chunking and reordering in dealing with the asymmetrical sentences

The valid recordings of the 19 participants were transcribed. Each participant interpreted eight asymmetrical sentences in the sentence condition and eight asymmetrical sentences in the text condition. To explore which strategy was used more frequently, we listened to all the audio recordings for the asymmetrical sentences and made a judgement based on their oral delivery along with the transcribed TT. The criteria for identifying the adopted strategy were straightforward since all judgements were based on whether or not the original word order was changed. If chunking was employed, the asymmetrical parts were segmented into shorter units and rendered sequentially. In contrast, if, for example, the English RC as the post modifier was placed before the head noun in the Chinese output, the sentence was considered to be a reordered one. Few participants changed their strategy. One attempted to reorder the original sentence but soon decided to chunk the sentence instead: he may have anticipated cognitive management problems due to reordering and changed his strategy. In this case, the strategy labelling was based on the final production.

Examples (2) and (3), both from the sentence condition, illustrate how the same sentence was chunked and reordered, respectively, by the interpreter trainees.

Example 2. Source text: Effects of global warming can be reduced // by enhancing tax incentives // to promote public transport and the use of cleaner energy.

Target text 1: 全球变暖的影响是可以得到解决的，可以减少的，我们可以通过提高税收刺激的办法，通过推动公共交通和清洁能源的使用。

Effects of global warming can be resolved, can be reduced, we can enhance tax incentives, we can promote public transport and using clean energy.

Target text 2: 全球变暖的影响是可以，是能够，被通过增强税收激励，来促进公共交通发展，通过使用清洁能源，来实现减少的。

The effect of global warming can, BEI,[2] *through enhancing tax incentives, to promote public transport, through using clean energy to realize the reduction.*

2

In Example (2), the first target sentence is a typical example of chunking; the original word order was retained in the target output. The participant divided the sentence into several shorter segments and interpreted them in sequence by adding logical links between the segments. In contrast, the second version demonstrates a non-linear approach. The reformulation of 'be reduced', the passive verb, was delayed and temporally stored in the participants' memory for integration with the agent '*enhancing tax incentive … energy*', which might increase short-term memory load and coordination efforts.

[2] The BEI structure is a key way of expressing the passive voice in modern Chinese. BEI (被) is used as a marker of passive construction but is not the only way to create the passive verb form in Chinese (Chappell & Shi 2016). The following example is a typical form of passive construction in Chinese.
Example
书被他拿走了
Book BEI he take.
(The book was taken by him.)

Example 3. Source text: Today leaders gather here to discuss the problems that all nations should pay close attention to and take actions to address.

Target text 1: 今天各位领导人齐聚在这里来讨论这些问题，也就是所有国家都应该密切关注并采取措施来解决的问题。

Today leaders gather here to discuss this problem. That is all nations should pay close attention to and take measures to address DE problem.

Target text 2: 今天各位领导齐聚于此，来讨论各国都应该关注并且积极解决的问题。

Today leaders gather here to discuss all nations should pay attention to and take measures to address DE problem.

Example (3) illustrates how the participants processed the RC structure by chunking and reordering. In the first target version, the participant split the original sentence with ‘*that*’ as the cutting point and interpreted the two clauses sequentially by inserting ‘也就是 (*that is*)’ between them for the sake of coherence. A reordering strategy was employed in the second version by moving the back-loaded RC in the source sentence to precede the head noun as a pre-modifying structure.

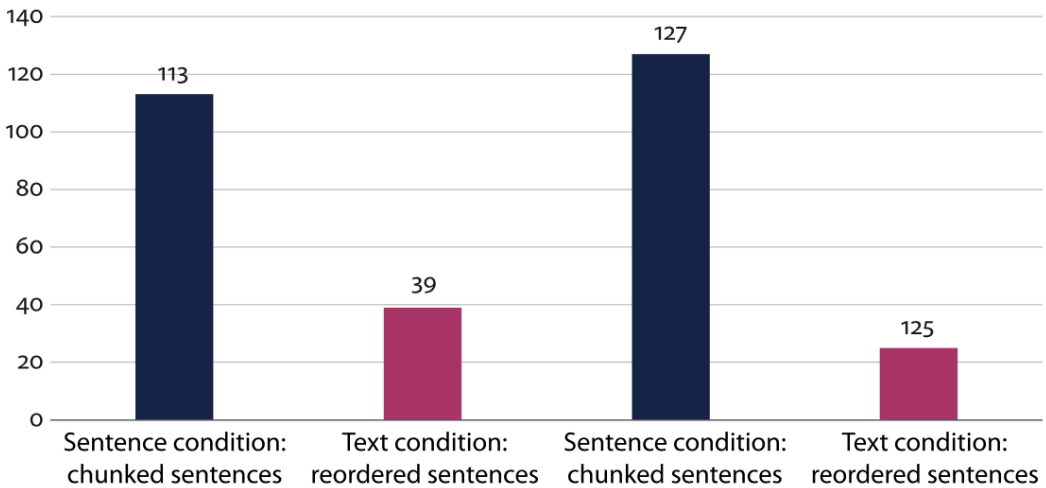

Figure 1. Frequencies of chunking and reordering in the two task conditions

Figure 1 demonstrates that chunking was the primary strategy in both conditions. The 19 participants sight translated 152 asymmetrical sentences in the sentence context and the text context. In the sentence condition, 113 sentences were interpreted through chunking, accounting for more than 70% of the total. Only 39 sentences were reordered. This gap in overall frequency was greater in the text context, in which 127 sentences were chunked, consisting of more than 80% of the total.

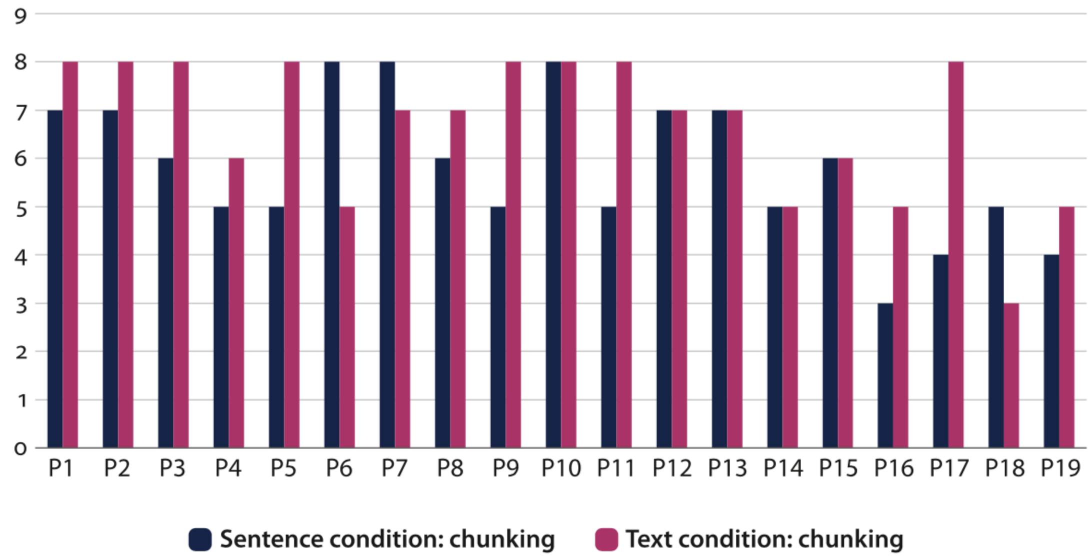

Figure 2. Frequencies of chunking for each participant in the two task conditions

To better capture whether or not the task condition affects strategy preference and, if so, how, we present the participants' individual data on the frequency of chunking in both conditions. Among the 19 participants, one (P10) chunked all 16 asymmetrical sentences in both conditions. As for the others, 11 participants chunked more sentences in the text context than in the sentence condition, with eight of them chunking all the asymmetrical sentences in the text condition. Four participants (P12, P13, P14, P15) chunked an equal number of asymmetrical sentences in both conditions. Only three participants (P6, P7, P18) applied reordering with a higher frequency than chunking in the text condition.

The results shown in Figure 2 indicate an impact of task condition on participants' strategy choice: more than half of the participants increased their reliance on chunking in the text context. To examine whether or not their strategy preference was influenced by the amount of contextual information available, a generalized mixed-effects model was fitted for the choice of strategy (chunking vs reordering) as the binary dependent variable. The predictor of the model was 'condition' (sentence context vs text context) and the random factors were 'participant' and 'sentence'. Although chunking was applied more frequently in the text context, the impact of task condition on strategy choice was not significant ($z = -1.05$; $p = 0.31$).

3.2 Strategy choice and overall cognitive load for processing word-order asymmetry

We used the *lme4* package (Bates et al. 2015) in the R environment (R Core Team 2015) to perform linear mixed-effect models (LMERs). Since the *lme4* package does not calculate p-values, the *lmerTest* package (Kuznetsova et al. 2017) was applied by using Satterthwaite approximations. Compared to the traditional ANOVA, this inferential method can better capture the individual differences between experimental sentences and between participants. The fixed effects of the model include two predictors: strategy (chunking and reordering) and condition (sentence context and text context). To account for between-participant and between-sentence variations, we added intercepts for 'participant' and 'sentence' as random effects. For the model selection, we adopted a forward selection approach, starting with a null model. We then gradually added the fixed effects, ending with the interaction item between fixed effects. We first adopted DT and FC as the two dependent variables. DT includes all fixations and saccades for processing the whole sentence, irrespective of when they take place. FC refers to the total number of fixations on the sentence. DT and FC have been widely used in translation process research as indicators of the overall cognitive load. Longer DT and more frequent fixations reflect the increasing task difficulty (e.g., Clifton et al. 2007; Hvelplund 2014; Rayner 2009). Two LMER models were fitted for DT and FC. The participants' DTs were logarithmically transformed due to a skewed distribution based on visual inspection, but their mean values were reported as non-transformed for ease of interpretation. Descriptive statistics are reported in Table 1 and the results of the R models are displayed in Table 2.

Table 1. Mean (*SD*) values of eye measures for overall cognitive load associated with strategies

	Chunking	**Reordering**
Dwell time (DT) (ms)		
Sentence context	19421 (5300)	21608 (6095)
Text context	15381 (4362)	18138 (5432)
Fixation counts (FCs)		
Sentence context	52 (17)	56 (18)
Text context	61 (16)	67 (18)

Table 2. Analysis of overall cognitive load (* $p < 0.05$)

Measure	Effect	Estimate	Standard error	*t*-value	*p*
Dwell time (DT)	Strategy (R→C)	−0.04	0.01	−2.8	0.005*
	Condition(D→S)	0.09	0.02	3.9	0.001*
	Strategy × condition	0.005	0.03	0.2	0.85
Fixation counts (FCs)	Strategy(R→C)	−4.3	1.9	−2.28	0.01*
	Condition(D→S)	−9.7	2.9	−3.3	0.004*
	Strategy × condition	1.1	3.75	0.29	0.77

Note.
C: chunking; R: reordering; D: text condition; S: sentence condition

As shown in Tables 1 and 2, there was a strong effect of strategy choice on the participants' cognitive load. In the interpretation of an asymmetrical sentence, reordering yielded significantly longer DT than chunking across both conditions ($t = -2.8$, $p = 0.005$). Similarly, there were considerably more fixations in reordered sentences than in chunked ones, irrespective of condition ($t=-2.28$, $p=0.01$). Chunking turned out to be a strategy for handling word-order asymmetry that requires less effort. As for the modulating effect of task condition, both chunking and reordering consumed significantly longer time in the sentence context than in the text context ($t = 3.9$, $p = 0.001$). However, data on FC exhibit a reverse direction in that STR required significantly more effort when more contextual information was available. Processing under the text context resulted in considerably more fixations than under sentence context, irrespective of the strategies used ($t=-3.3$, $p = 0.004$).

3.3 Strategy choice and local cognitive load for processing word-order asymmetry

To explore further whether or not online reading behavior was affected by the strategy, we compared the rereading rate in the asymmetrical sentences processed through the two strategies. Rereading rate refers to the probability of rereading the source word and is calculated as the proportion of fixations in interpreters' second-pass reading. Fixations during this period are generally associated with later-stage processing, such as the correction of miscomprehension and semantic/ syntactic integration (Rayner 1998; Titone et al. 2016). Therefore, a higher rereading rate is related to greater processing difficulties. As word-based eye-data analysis has a lower tolerance for fixation drift during recording, we filtered the data further and identified 13 participants for the rereading rate analysis. We fitted one linear mixed-effects model for the rereading rate by including the same predictors and random effects. The results of the analysis are reported in Table 3.

Table 3. Analysis of rereading rate (* $p < 0.05$)

Measure	Effect	Estimate	Standard error	*t*-value	*P*
Rereading rate	Strategy(R→C)	−0.03	0.01	−2.22	0.02*
	Condition(D→S)	−0.05	0.02	−3.20	0.01*
	Strategy × condition	−0.02	0.03	−0.72	0.47

Note.
C: chunking; R: reordering; D: text condition; S: sentence condition.

As shown in Table 3, the effect of strategy choice was confirmed under both conditions (t=−2.22, p=0.02). In the sentence context, reordering elicited a significantly higher rereading rate (M=0.56, SD=0.12) than chunking did (M=0.51, SD=0.13). Similarly, in the text context, the rereading rate for the reordered sentences was significantly higher (M = 0.61, SD = 0.13) than that for the chunked sentences (M=0.57, SD=0.11). In addition, a significant effect of the condition was detected. The participants were more likely to reread the prior words in the text context regardless of which strategy they applied (t = −3.2, p = 0.01).

Figures 3 and 4 display the fixation sequence in a sentence with PC processed through reordering and chunking, respectively. The fixation sequence plots are drawn based on the original eye-tracking data on the same sentence rendered by different participants. The number in the plots represents the order of fixations. For example, '1' refers to the first fixation and '20' represents the 20th fixation since the beginning of the trial. The number of lines of fixations under the words reflects the number of reading passes. As shown in Figure 3, there are four lines for fixation under the word 'can', which means this source word was passed by four times. The first line represents the first run, in which the sixth fixation constitutes the first-pass reading time (also known as the first-pass 'fixation time') (Yan et al. 2013). First-pass reading refers to the total time spent in the word region, from first entering it until the eyes moved to the left or right region. It is often studied as an early-stage or initial processing, such as word retrieval (Rayner et al. 1989). Below the first run, there are three lines of fixations, which together account for the second-pass reading time (in other words, excluding the first-pass reading time) (Dussias 2010). All the fixations occurring after the first run, no matter which line they belong to, are categorized as second-pass fixations or re-fixations, which are indicative of processing difficulty, re-analysis and integration (Yan et al. 2013).

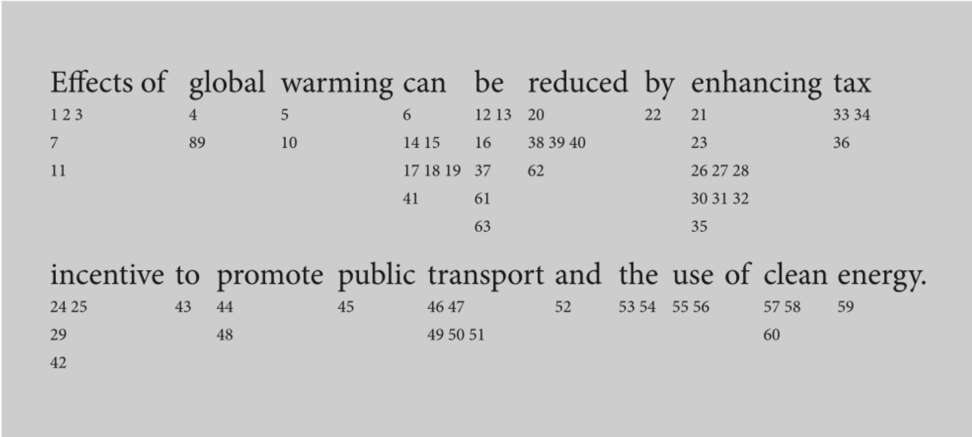

Figure 3. Fixation sequence for the PC processed through reordering

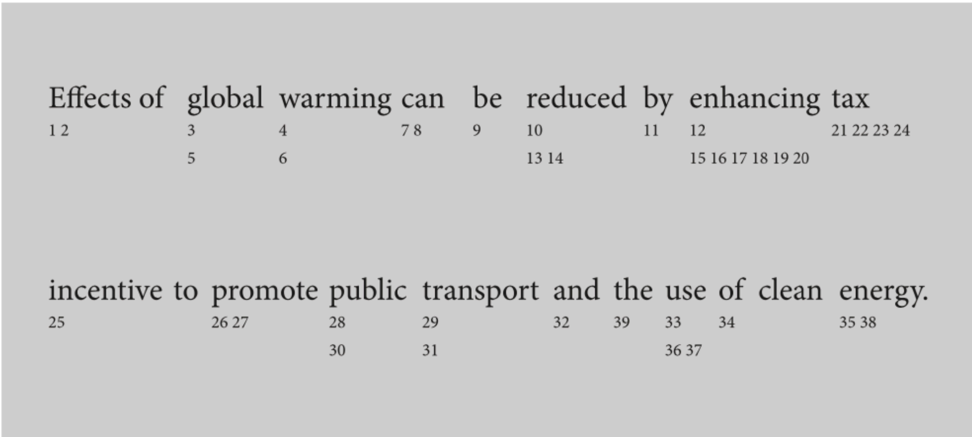

Figure 4. Fixation sequence for the PC processed through chunking

As shown in Figure 3, the online reading in the reordered sentence was more fragmented, as demonstrated by the frequency of second-pass fixations. ‘Be reduced (be + passive verb)’, the asymmetrical region in Figure 3, was read five times. After the first pass of reading (Fixations 12, 13), the participant regressed to the word on its left (Fixations 14, 15, on ‘can’) and moved her eyes back to the PC region for a second round of processing (Fixation 16). Then she shifted her attention again to ‘can’ (Fixations 17–19) before directing her eyes once again to the asymmetrical region (Fixation 20 on ‘reduced’). This shows that her fixations frequently moved in and out of the PC region. Specifically, it was after the fixations on the final words (Fixations 57–60, on ‘clean energy’) that her eyes moved back to the PC region for the last-stage integration. This reading mode reveals a long-distance attention shift between the earlier regions and later regions of the sentence, implying conscious effort on the part of the participant. In contrast, the fixation path in Figure 4 shows that rereading was far less frequent with all the words being fixated on only once or twice. In addition, most fixations occurred between neighboring words without long-distance regressions, indicating a more local processing mode. Through chunking, the participants reformulated their sentences at the level of a word or a short segment instead of moving their eyes back and forth across a wider scale. Therefore, eye movements during chunking were smoother and more successive, with fewer regressions and less re-analysis.

Likewise, the difference between chunking and reordering according to online reading can be seen in Figures 5 and 6, which illustrate how the RC was rendered in the asymmetrical sentence. As shown in Figure 5, the head word may have been perceived and comprehended during the first-pass reading (Fixation 12) but it was read for a third and a fourth time (Fixation 29 and Fixations 33, 34) after the retrieval of ‘actions’ (Fixations 27, 28) and ‘address’ (Fixations 31, 32). We infer that the participant, after the first contact with the relative pronoun (Fixation 13 on ‘that’) may have immediately attempted to reorder the RC by continuing to read the remaining parts for the purpose of integrating them with the previous head word. This fixation pattern reflects the analysis in Section 3.2, which shows that a higher cognitive load is involved in reordering, possibly due to the higher costs of storing information during frequent attention shifts, especially long-distance ones.

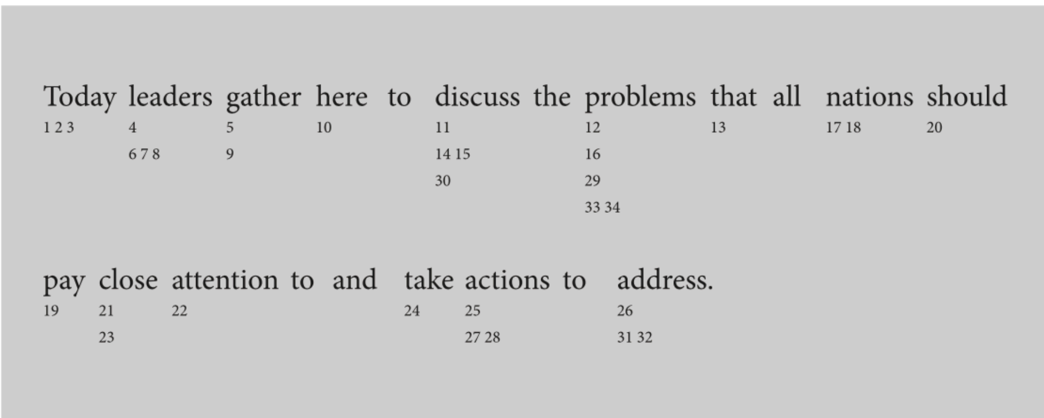

Figure 5. Fixation sequence for the RC processed through reordering

3.4 Problems in the production of chunked sentences

Effective linking devices and coherence were absent in the asymmetrical sentences chunked by some participants. Examples (4) and (5) demonstrate the ways in which the same PC sentence was chunked by two participants ('//' in the sentence signals the cutting point at which the sentence was segmented).

Example 4.Source text: These suggestions should be taken seriously by all decisionmakers working together to set up new world orders at this forum.

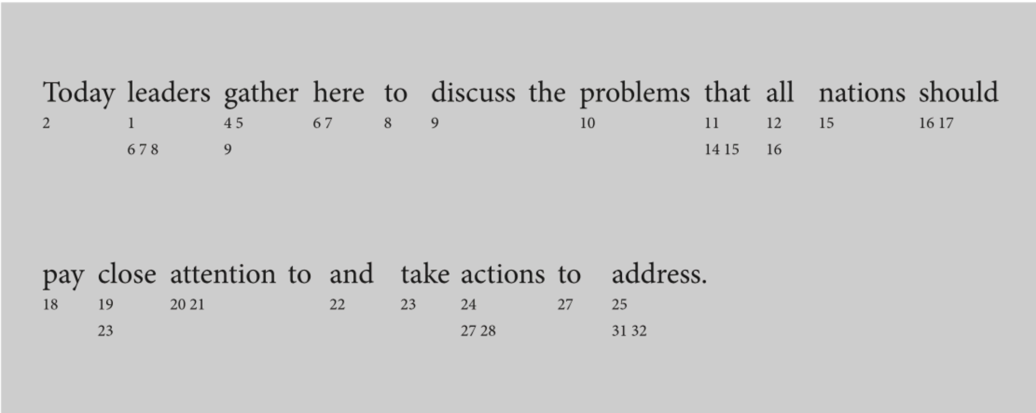

Figure 6. Fixation sequence for the RC processed through chunking

Target text: 这一建议应该被采纳 // 被严肃地对待 // 所有的决策者都 // 采纳 // 去构建新的世界秩序 // 在这个论坛上。

This suggestion should be taken // be seriously taken // all decision-makers should take // to build new world orders // at this forum.

In successful chunking, an interpreter has to identify the operative segments by splitting the sentence at appropriate locations and establishing logical links between the segments. Example (4) shows a problematic delivery in the sense that the target sentence was made up of segments without logical links, resulting in an awkward sentence.

In contrast, Example(5) illustrates another participant's more effective chunking of the same source sentence.

Example 5.

Source text: These suggestions should be taken seriously by all decisionmakers working together to set up new world orders at this forum.

Target text: 这些建议需要被认真考虑 // 这些是所有决策者的建议 // 他 们要合作构建一个新的世界秩序 // 就是在本次论坛上。 *These suggestions need to be seriously* *considered // these are suggestions of all decision-makers // they work together to set up new world orders // it is at this forum*.

The original sentence was divided into four segments connected by the use of cohesive devices such as '这些是 (these are)' and '就是 (it is)'. It is possible that the participant identified the passive marker 'be taken seriously' and chunked the sentence at this point. The agent following 'by' was not incorporated into the previous structure, but was used instead as the starting point of a new clause by adding '这些是 (these are)'. This related the emerging long agent to 'reduced', therefore allowing the sentence to progress.

4. Discussion

4.1 Chunking as the primary strategy adopted for word-order asymmetry

Our first research question focuses on the frequency and distribution of the strategies (chunking and reordering) in the handling of word-order asymmetry. The data analysis demonstrated that chunking was used far more frequently than reordering. Individual data on strategy distribution reveal that more than half of the participants increased their reliance on chunking in the text context, although the effect of task condition on strategy preference did not reach statistical significance. This may have been due to the small sample size in the study.

The participants' consistent preference for chunking might reflect their attempt to reduce their cognitive effort during STR. Given their limited number of cognitive resources, interpreters generally give priority to any strategy that requires the least amount of processing effort (Shlesinger 2003). According to the literal translation hypothesis (Tirkkonen-Condit 2005), syntactically literal translation that pertains to structures of the source language is a default procedure in translation, which is believed to trigger less cognitive effort (Ivir 1997; Schaeffer & Carl 2013). Chunking, characterized by syntactic linearity, is a similar strategy.

In our second research question (2c), we aimed to investigate the impact of context. In particular, we ask whether or not the amount of contextual information affects participants' strategy preference and whether or not text context alleviates cognitive load regardless of which strategy is applied. It was expected that when more contextual information was available, processing would be easier, regardless of the strategy applied. However, this assumption was only partially supported. The results in Section 3.1 show that significantly shorter DTs were found in the text context, irrespective of the strategy preference. This may be because words became more predictable from the prior context (Clifton et al. 2007; Ehrlich & Rayner 1981). Furthermore, the contextual information in the text condition might have preactivated 'some concepts, relations and schemas related to comprehension' (Setton 1999: 97), which enabled a time-efficient processing. However, the facilitation effect of context was not supported by the results regarding FC: significantly more fixations occurred in the text context irrespective of the strategy used. Similarly, the rereading rate in the text context, as reported in Section 3.3, was considerably higher than in the sentence context.

We therefore infer that processing in the text context required more effort in that the participants made considerably more fixations and regressions within a shorter time period, compared to the sentence context. Several factors may account for this context-induced effort. First, processing in the text context may have induced a greater memory burden because sentences need to be temporarily stored in order to establish discourse representation incrementally (Cowles 2003). During STR, the participants may have stored the earlier processed contextual information in their short-term memory for comprehending the whole sentence, which requires more memory resources. Second, the visual interference caused by the constant presence of written information (Agrifoglio 2004) might be more pronounced in the text context. Shreve, Lacruz and Angelone (2011) found that during STR all second paragraphs in STs appeared to require more effort for interpreters to process them than the first paragraphs, which appeared to indicate increasing visual interference as the task progressed. It is possible that semantic processing in the text context required a continuous integration of linguistic information across words, clauses and sentences (Sedivy et al. 1999), and that this resulted in more frequent fixations and rereading.

4.2 Chunking was less cognitively demanding than reordering as measured by eye movements

Our second research question (2a and 2b) asks how the participants' cognitive processing was affected by their strategy preference. We answered it by observing the cognitive load and real-time processing behavior illustrated by participants' eye-movement data.

We hypothesized that reordering would involve greater cognitive load as indicated by DT and FC, and this pattern would apply to both task conditions. This assumption was partly supported by the data. In both task conditions, reordering elicited significantly longer DT and more frequent fixations than chunking. Realtime processing patterns confirmed the benefits of using chunking to cope with asymmetrical sentences. The syntactic linearity achieved through chopping up a sentence led to more time-efficient processing, the avoidance of additional costs due to long-distance attention shifts and the short-term maintenance of the previously processed information. In contrast, reordering was more cognitively taxing, owing to the long-distance integration involved.

In addition to the overall cognitive load, we also analysed the local cognitive load by measuring the rereading rate. It was found that rereading occurred far less frequently in the chunked sentences than in the reordered sentences in both conditions. It is possible that chunking enabled segment-by-segment processing, so that the SL could be retrieved and encoded locally. In contrast, when reordering a sentence, the participants had to constantly read back and forth in order to perform structural integration. To summarize, the reading pattern during chunking seemed to be less cognitively demanding than that during reordering.

4.3 Chunking is more than sentence dividing

Although chunking was consistently preferred over reordering in both task conditions and was cognitively more efficient in terms of DT and rereading rate, the chunked sentences in the TL were not without problems. For instance, the examples in Section 3.4 show a lack of coherence. One possible reason for this is that the participants had already been too overloaded by asymmetry-induced difficulty and therefore lacked the additional attention resources needed to achieve textual coherence.

5. Conclusion

This study explored the cognitive processing that underlies chunking and reordering, two major approaches to managing word-order asymmetry in interpreting. The significantly greater cognitive load and frequent attention shifts invoked by reordering, as shown in the eye-tracking data, offer empirical support for using chunking as a cognitively relieving tactic to deal with asymmetry structures. This study also highlights the importance of logical coherence because the use of chunking as a strategy could result in sentences comprising fragments that lack effective connections. These findings reveal that giving attention to the cognitive mechanism associated with chunking and reordering can be useful for interpreter training.

This study has several limitations. First, in practice, asymmetrical sentences might be strategically skipped over if they are considered to be irrelevant or detrimental to the communicative effect (Gile 2011a). They can also be omitted due to problems with processing capacity (Gile 2011a). Therefore, interpreters' responses to word-order asymmetry in real life may be quite different from what is observed in an experiment. It would be interesting to observe how interpreters tackle syntactic asymmetry in authentic interpreting performances – for example, by way of corpus-based exploration. Second, the text presentation in the text condition (i.e., the position of the experimental sentences in the upper versus the lower parts of the screen) might have influenced the participants' eye movement and therefore should be taken into consideration in future designs. Finally, the study involved only interpreting trainees with no between-groups comparisons with professional interpreters, who may demonstrate the use of different strategies. Another limitation of the study is the lack of an analysis of the errors and disfluencies in the interpreting output, which can indicate the effects of strategy on the interpreting quality.

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Appendix A. Experimental materials for STR in the sentence context

Asymmetrical sentences

We are making efforts to protect world peace that people have been looking forward to and many countries are fighting for.

Addressing the migration crisis is an enormous challenge which all European countries should face up to and work hard to resolve.

During the past seven decades, the choices that we have made as a responsible major country have outlined a better future.

Today leaders gather here to discuss the problems that all nations should pay close attention to and take actions to address.

Effects of global warming can be reduced by enhancing tax incentive to promote public transport and the use of cleaner energy.

The United Nations during the past decade has been motivated by our commitment to a multilateral, open and tolerant global system.

These suggestions should be taken seriously by all decision makers working together to set up new world order at the forum.

We believe that our economy can be boosted by reducing the trade barriers and creating a fair and transparent trade environment.

Symmetrical sentences

After the earthquake, we are doing our best to help the victims and provide necessary support to help rebuild their home.

Our organization will continue to protect the rights of women, making sure that they get the opportunity for education and jobs.

We hope that at this conference we will achieve meaningful plans to deal with climate change and build a sustainable future.

To make full use of globalization, we should welcome and encourage reforms and create a more transparent trade environment.

To address this great challenge, the only way for us is to defend the international order and protect our common rules and values.

In order to deal with this challenge, several major countries including US and China, have announced plans to boost the economy.

The UN confirms that Syria has used chemical weapons on its people and countries need take necessary measures to stop it.

If this system was no longer capable of preventing violence, we would have to redouble our efforts for an alternative plan.

Appendix B. Experimental materials for STR in the text condition

Note: The asymmetrical sentences are bolded. The symmetrical sentences are italicized.

Text A (adapted from Welcome Remarks by H.E. Le Luong Minh Secretary-General of ASEAN Day Celebration in 2016)

Good morning, ladies and gentlemen. Thank you for joining us on this historic occasion and celebrating the anniversary of ASEAN. *Thanks to years of hard work, ASEAN has grown into a strong and influential power, upholding regional peace, security and stability*. We are facing a historic moment. **Today we gather here to honour the success that ASEAN has achieved over the years in reducing poverty and fostering growth**.

ASEAN is a stable and dynamic community. One of the major achievements is our regional roadmap for development. *We are glad to see that the roadmap has brought tangible benefits including enhanced regional influence and a more robust economy*. **In addition, the business and trade environment has been enhanced by our competitive policy and the expansion of digital commerce platform**.

ASEAN is also a young region: *the community is full of potential given that more than 30% of our combined population are 35 years or even younger*. The future of ASEAN depends on its people. **ASEAN's success will be measured by how it brings about benefits to the young generation and lives up to their expectations**. To ensure a better future, *the member states should work hard to set up an open and inclusive platform to support their people's ideas and efforts*.

We are living in an era of change and challenges. **I believe that ASEAN will continue to function as an important channel that countries aspiring to peaceful development can rely upon**. And thank you again for joining us today! (249 words)

Text B (adapted from President Sirisena's speech at the Plenary Session of the Boao Forum for Asia in 2015)

Good evening, ladies and gentlemen. It is my great pleasure to participate in this forum. *Today world leaders and the business community gather here for our shared vision: to strengthen dialogue and to promote the growth*. The 21st century is Asia's century. **However, the regional prosperity has been threatened by high consumption, an ever-growing income gap as well as lack of governance**.

It's time for concrete actions. **We have been working on the economic reforms that our investors**

and partners have been looking forward to over the decades. The reforms are effective: *It has made the business climate more favorable and attractive, created more jobs and has also expanded our global market share*.

Ladies and gentlemen, Sri Lanka is committed to such actions. *We are fully aware that deep reforms and exchanges can help small nations to realize the potential and achieve sustainable growth*. Sri Lanka has enjoyed a high growth rate. **The island has a strategic location that nations pursuing trade and commercial exchange with other regions can make full use of**.

Ladies and gentlemen, Asia has a long and proud history of cooperation. **Asian people have been motivated by their own values, identities and the pursuit of a fully integrated and more prosperous Asia**. We are confident that *this important forum can play a vital role in encouraging dialogues to explore the development path and achieve our common vision*. Thank you! (233 words)

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