Early, but not overwhelming: The effect of prior context on segmenting overlapping ambiguous strings when reading Chinese

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Abstract

The current study investigated how the prior context influences word segmentation of overlapping ambiguous strings when reading Chinese. Chinese readers' eye-movements were recorded as they read sentences containing a 3-character overlapping ambiguous string (ABC), where both AB and BC were 2-character words. In the informative condition, prior contexts provided syntactic information that supported either the first word segmentation (AB-C) or the second word segmentation (A-BC). The neutral condition did not provide syntactic constraint for word-segmentation. The post-target contexts were syntactically consistent with either the first word (AB-C), or the second word (A-BC) segmentation. Results showed that there were higher skipping rates and shorter first-fixation durations on the overlapping ambiguous string region in the informative AB-C condition than in the informative A-BC condition; while no difference between the AB-C and A-BC segmentation types was found in the neutral condition. Readers still made regressions into the overlapping ambiguous string region in the informative condition. These results imply that readers use sentence context information immediately to segment the overlapping ambiguous words, but they do not use the context information fully. The first word (AB) has processing advantages over the second word (BC), suggesting a left-side word advantage.

Keywords: Chinese reading, eye movements, word segmentation, prior context

Introduction

Word recognition is the basis of sentence and discourse comprehension during reading. A number of studies have shown that words play a very important role in reading Chinese (Bai, Yan, Liversedge, Zang, & Rayner, 2008; Hoosain, 1992; Li, Bicknell, Liu, Wei, & Rayner, 2014; Li, Gu, Liu, & Rayner, 2013; Zang, Liang, Bai, Yan, & Liversedge, 2012). However, different from alphabetic languages like English, there are no interword spaces to mark word boundaries in Chinese texts. This can create a challenge for Chinese readers to segment unspaced Chinese text into words. Because words are always embedded in sentences during natural reading, it is important to know how the sentence context affects word segmentation.

Sentence context is important for word segmentation, and it is especially important in situations where word boundaries are ambiguous. One example of an ambiguous word boundary is overlapping ambiguous strings (three-character strings; ABC) where the middle character can create distinctive words with the characters to both its left (word AB) and its right (word BC) (Gan, Palmer, & Lua, 1996; Li, Gao, Huang, & Li, 2003; Yen, Radach, Tzeng, & Tsai, 2012). For example, in the overlapping ambiguous string *选手套* (pronounce *xuan shou tao,* as shown *in pinyin*), the first two characters constitute a word *选手* (which means *player*), while the middle character makes up a second word *手套* (which means *glove*) with the third character. Hence, the overlapping ambiguous strings can be segmented as two constructions: AB-C (e.g., 选手-套) or A-BC (e.g., 选-手套). Overlapping ambiguous strings occur quite frequently in Chinese texts and the probability of occurrence is 3.6% (Yen et al., 2012). Previous studies have shown that readers have to pay more attention to distinguish and segment overlapping ambiguous strings than they do to other unambiguous words (Hsu & Huang, 2000a, 2000b; Yen et al., 2012).

Many theories have been proposed to explain how Chinese readers process overlapping ambiguous strings during Chinese reading (Inhoff & Wu, 2005; Li, Rayner, & Cave, 2009; Ma, Li, & Rayner, 2014; Ma, Pollatsek, Li, & Li, 2017; Perfetti & Tan, 1999). Perfetti and Tan (1999) proposed a two-character assembly strategy which assumes that the first two characters of the overlapping ambiguous string have an absolute priority to constitute a word, and these two characters would not be assigned to any following words. To support this claim, they conducted one eye-tracking experiment, where they embedded three-character overlapping ambiguous strings (e.g., *照顾客*, which means *according to the customer*) in the sentences. In their experimental sentence, the correct segmentation of overlapping ambiguous string was always an A-BC construction. In the control condition, the first character of the ambiguous string was replaced with another synonym (e.g., *按顾客*) so that the first character did not constitute a word with the second character and the three-character string was not an overlapping ambiguous string anymore. They found that the reading times for the three-character target region in the overlapping ambiguous strings were longer than those in the control condition. Based on these findings, the authors suggested that readers combined the first two characters of the overlapping ambiguous strings into a word in first-pass reading. Since this kind of segmentation was not consistent with sentence context, readers need to take extra time to correct the segmentation, so readers need a longer time to process the overlapping ambiguous strings.

A later study conducted by Inhoff and Wu (2005) showed that readers might not process characters in a strict serial order, and thus they do not always assign the middle character of the overlapping ambiguous string to the word on the left. They conducted an eye-tracking study where participants read sentences with a four-character string (ABCD). The first two characters in the four-character string constituted a word (AB), and the last two characters constituted another word (CD). In the ambiguous condition, the central two characters also constituted a two-character word (BC; e.g., in the string *专科学生*, which means *college student*, there were three words, *专科, 科学,* and *学生*). In contrast, in the control condition, the central two characters did not constitute a word (e.g., in the string *专科毕业*, which means *college graduation*, there were two words, *专科* and *毕业*). The results showed that first-pass reading times and total reading times were longer in the ambiguous condition than that in the control condition. These data indicate that Chinese readers do not group characters in a strictly serial order. Instead, all of the possible word candidates in the perceptual span are activated, so that a character which belongs to the left-hand word can also be part of next word. Inhoff and Wu referred to this as a *multiple activation hypothesis*, and the influence of BC on the processing of ABCD was consistent with this hypothesis.

Once all of the possible words are activated, what happens to them? To address this question, Ma, Li and Rayner (2014) inserted Chinese overlapping ambiguous strings into one of the two sentence frames so that it could be segmented as either AB-C or A-BC, according to the disambiguating information that came after the overlapping ambiguous strings. In addition, they also manipulated the word frequencies of word AB and word BC, resulting in high-low frequency (i.e., the frequency of the first word was higher than the second word) and low-high frequency conditions (i.e., the frequency of the first word was lower than the second word). Hence, the segmentation (AB-C or A-BC) that was determined by the word frequency fitted into the context in one sentence (the *fit condition*) but did not fit in the other sentence (the *misfit condition*). They found that second-pass reading times were shorter and readers made fewer regressions to the ambiguous region in the fit conditions than in the misfit conditions. These results indicated that Chinese readers were more likely to segment the string ABC as A-BC rather than AB-C when the second word (BC) had a higher frequency than the first word (AB). Thus, Ma et al. proposed the *competition hypothesis* to explain these findings. Based on this hypothesis, all the words in the perceptual span can be activated and compete with each other for a single winner. Once a word unit wins the competition, the word it represents is identified and is also segmented from text. Any word has a chance to win the competition if its activation is high enough, and word frequency is an important factor in determining which word wins the competition. Higher-frequency words will win the competition more often and the overlapping ambiguous string will be segmented differently depending on the frequencies of word AB and word BC. In a later stage, readers check whether the initial segmentation fits in with the sentence context, and they may need extra time or even go back to correct the initial segmentation if it is wrong.

In the study by Ma et al. (2014), Chinese readers needed two stages of processing to segment the overlapping ambiguous strings. This might have been caused by the fact that its preceding context was neutral in regards to segmenting the overlapping ambiguous strings. What would happen if prior context provided some bias regarding how to segment the overlapping ambiguous strings?

There are three possibilities with respect to how prior sentence context affects word segmentation during Chinese reading. The first possibility is that readers use sentence context information immediately when segmenting the overlapping ambiguous strings. Thus, they make an initial segmentation with the help of sentence context information. This hypothesis is similar to the constraint-based models (MacDonald, Pearlmutter, & Seidenberg, 1994; McRae, Spivey-Knowlton, & Tanenhaus, 1998; Spivey & Tanenhaus, 1998; Trueswell, 1996; Taraban & McClelland, 1988; Trueswell, Tanenhaus, & Garnsey, 1994; Tyler & Marslen-Wilson, 1977), which assume that syntactic ambiguity resolution is a continuous and constraint-satisfaction process, and processing difficulty occurs when there is inconsistent biasing information. Specifically, all analyses are computed in parallel and all constraints are used immediately during sentence parsing and interpretation. Thus, prior context can exert its effect immediately when readers encounter overlapping ambiguous strings. We will refer to this possibility as the immediate hypothesis.

Another possibility is that readers do not immediately use sentence context information when they encounter it. Instead, readers might still use a two-stage segmentation strategy as proposed by Ma et al. (2014). In the first stage, readers segment the overlapping ambiguous strings according to the competition hypothesis

(Ma et al., 2014), and some factors such as word frequency and the left-side word advantage caused by reading direction (which will be introduced later) affect the competition between AB-C and A-BC segmentations, resulting in an initial segmentation outcome. Different from the immediate hypothesis, this account assumes that sentence context does not affect the first stage of competition when processing the overlapping ambiguous string. During the second stage, readers use sentence context information to check whether the initial segmentation outcome fits in with sentence context. The idea that sentence context exerts its effect at a later stage is similar to the two-stage models proposed in syntactic ambiguity resolution studies (Ferreira & Clifton, 1986; Ferreira & Henderson, 1990; Frazier, 1987; Frazier & Rayner, 1982). The two-stage models presume that the processor draws on a restricted range of pure syntactic principle to compute an initial analysis in the first stage, and uses other information sources to check whether it is correct during the second stage. The garden-path model (Frazier, 1978, 1987, 1990; Frazier & Clifton, 1996; Frazier & Fodor, 1978) is a typical example of the two-stage models, which assumes that the initial analysis is based on syntactic strategies, such as the minimal attachment principle and late closure principle, and prior context plays the role of reanalysis in the second stage. We will call this the two-stage hypothesis.

Many factors affect the initial stage of word segmentation in Chinese reading. Word frequency and the left-side word advantage caused by reading direction are two of them. As stated above, a higher-frequency word has an advantage over a lower-frequency word, and thus the high frequency word might be segmented earlier during the initial segmentation process (Ma et al., 2014). Reading direction can also affect word segmentation. Chinese is read from left to right, and accessing words in the right order is essential for successful comprehension (Rayner, Angele, Schotter, & Bicknell, 2013). Since Chinese readers read from left to right, the AB-C construction may have advantages over the A-BC construction. Due to the limitation of visual acuity, compared with the word on the right, the word on the left is closer to the foveal fixation when the eyes move from left to right, and more visual attention is allocated to the word on the left. Consistent with the assumed left-side word advantage, the study mentioned above (Perfetti & Tan, 1999) suggested that words are processed in a strictly serial order from left to right and Chinese readers prefer to combine the first two continuous characters in the ambiguous string into a word.

A similar segmentation problem has been examined with regard to the ambiguous trimorphemic words during the reading of an alphabetic text (de Almeida & Libben, 2005; Pollatsek, Drieghe, Stockall, & de Almeida, 2010). Many trimorphemic words are semantically and structurally ambiguous. Taking *UNLOCKABLE* as an example, there are three morphemes: UN, LOCK and ABLE. If one first attaches the prefix (i.e., UN-) to the root to get the left-branching structure UNLOCK-ABLE, the word means *can be unlocked*; if the suffix (i.e., -ABLE) is firstly grouped with the root to get the right-branching structure UN-LOCKABLE, it means *cannot be locked*. Pollatsek et al. (2010) explored which interpretation was preferred and whether the preceding context had effects on the initial interpretation. They embedded ambiguous trimorphemic words into different sentences where the preceding context disambiguated the meaning in some sentences, while the preceding context did not disambiguate the meaning in other sentences. They found a left-branching preference for ambiguous trimorphemic words. When the previous context was biased to the right-branching structure, there were more go-past times on the ambiguous word than when the preceding context was neutral; while when preceding biasing context was consistent with the left-branching structure, there was no significant disruption in the processing of the ambiguous word compared to neutral context.

So far, we have discussed the two possibilities (immediate hypothesis and two-stage hypothesis) as if they are mutually exclusive. However, they are not necessary so. Readers may use sentence context information immediately to segment the words when they encounter the overlapping ambiguous strings, but they do not use sentence context information fully. As a result, in some trials, the sentence context does not override the segmentation based on either left-side word advantage or word frequency. If readers use context information fully, they would not make regressions into earlier parts of sentence to correct initial segmentation outcome when there are informative contexts. This is similar to the good-enough theory, which was proposed by researchers when they studied sentence processing (Ferreira, Bailey, & Ferraro, 2002). The good-enough approach states that language processing is sometimes only partial, shallow, and incomplete, which contrasts with the traditional view that language processing proceeds in a perfect manner. Several studies (Christianson, Hollingworth, Halliwell, & Ferreira, 2001; Ferreira, 2003), where participants were asked questions about the interpretation of sentences, found that garden-path sentences (i.e., the particular type of sentence where readers select one interpretation initially that is finally incorrect, and they hence make regressions to earlier part of text) were misinterpreted, and readers' interpretations were based on shallow processing or incomplete reanalysis. It suggested that, in many cases, comprehension is based on a parse of input that is good enough to respond to the current task, and sometimes readers may leave syntactic ambiguity unresolved (Swets, Desmet, Clifton, & Ferreira, 2008). It should be noted that the traditional good-enough theory usually assumes that readers do not fully process all the information in the sentence if it is not necessary. However, here we assume that Chinese readers do not use sentence context information fully when they process the overlapping ambiguous string during the first-pass reading. In some situations, the prior context may not be fully utilized during first-pass reading, so readers come up with a segmentation which is inconsistent with the context. If this happens, readers have to check and correct errors in the later stage. We will call this hypothesis the partial processing hypothesis.

In the current study, we conducted an eye-tracking experiment to assess the three hypotheses. We embedded overlapping ambiguous strings in sentences and asked participants to read sentences naturally while their eye movements were monitored. Prior context was manipulated to either provide information about word segmentation or not, leading to an informative context or a neutral context. We employed a syntactic constraint approach to construct the prior context (see the material section for details), which is an efficient way to generate syntactic expectations for next words (Brothers & Traxler, 2016). In half of the sentences, the prior contexts were constructed to generate syntactic constraints for upcoming text which helped readers with segmentation, supporting either the first word segmentation (AB-C) or the second word segmentation (A-BC), according to sentence context. This was the informative condition. In the other half of the text, the prior context did not provide any syntactic information for word segmentation and had no bias toward any segmentation type. Hence, these prior contexts were neutral. Moreover, post-target contexts also constrained the segmentation of the overlapping ambiguous string. In the AB-C segmentation condition, the first word segmentation (AB-C) was consistent with the sentence context, while in the A-BC segmentation condition, the second word segmentation (A-BC) was congruent with the sentence context. In addition, for all conditions, we controlled the frequency contrast of the first words (AB) and second words (BC) so that there was no significant difference between word frequencies of the words AB and the words BC.

The three different hypotheses had different predictions regarding the results of the overlapping ambiguous string region. If readers used the sentence context information immediately when encountering the overlapping ambiguous strings, predicted by the immediate hypothesis, early eye movement measures (such as first fixation durations and skipping rates) should be different between informative and neutral contexts. Specifically, when informative context supports the AB-C construction, which is consistent with the left-side word advantage caused by reading direction, first-fixation durations should be shorter and skipping rates should be higher than when the informative context favors the A-BC construction inconsistent with the left-side word advantage. Nevertheless, first-fixation durations and skipping rates should be comparable between the AB-C and A-BC segmentation conditions in the neutral context. Moreover, the immediate hypothesis also predicts no regressions into the overlapping ambiguous string region when prior sentence context was informative, since the readers will have already segmented the overlapping ambiguous strings successfully because of the previous informative context when they encounter the post context.

The two-stage hypothesis predicts a different pattern of results. Since initial segmentation doesn't draw on prior contexts, early eye-movement measures including first-fixation durations and skipping rates should show similar patterns in both the informative context and the neutral context. In the first stage of processing, readers only use the left-side word advantage caused by reading direction and the frequencies of competing words to determine an initial segmentation. Since word frequencies of AB and BC were comparable in this study, initial segmentation is mainly determined by left-side word advantage introduced by reading direction. That is to say, readers usually segment the overlapping ambiguous string ABC as AB-C. In the second stage, readers use prior sentence context information to check whether the initial segmentation is correct. When prior context conflicts with initial segmentation, readers might need to correct the initial segmentation. As a result, this hypothesis predicts longer gaze durations and more regressions out of the overlapping ambiguous string region in the informative A-BC condition compared to the informative AB-C condition. In addition, readers should make fewer regressions in the informative context than in the neutral context, because it is relatively easier to integrate texts with the help of informative prior context.

Finally, according to the partial processing hypothesis, readers use context information immediately, thus first-fixation durations and skipping rates should be different between the informative context and neutral context. In the informative AB-C condition, first-fixation durations should be shorter and skipping rates should be higher than those in the informative A-BC condition. First-fixation durations and skipping rates should be comparable between the AB-C and A-BC segmentation conditions in the neutral context. However, different from the immediate hypothesis, readers will not use the context information fully, thus they should make regressions into the overlapping ambiguous string region when encountering the post context because the initial segmentation was incorrect. Moreover, gaze durations should be longer and regression-out probabilities should be higher when the prior context information conflicts with the left-side word advantage, suggesting integration difficulties in this situation.

Methods

Participants

We estimated the priori power of the study by using the *powerSim* and *powerCurve* functions from the *simr* package (Peter, Catriona, & Phillip, 2018) to determine the required number of participants. First, we conducted a pilot study with ten participants and analyzed the pilot data with a linear mixed model (as described in the data analysis section), where the gaze duration on the overlapping ambiguous string region was the dependent variable. Then, based on the pilot data, we explored how the power varies as a function of the number of participants. The results indicated that forty participants had a power estimate of 85%, suggesting that 40 participants were enough to detect an effect with an effect size of 0.80 in this experiment (Brysbaert & Stevens, 2018; Cohen, 2013). Thus, forty participants (22 females and 18 males) were recruited to participate in the study. All of them were native Chinese speakers and had normal or corrected-to-normal vision. Their ages ranged from 18 to 30 years (M = 22.78 years, SD = 2.97).

Apparatus

Participants' eye movements were recorded by an SR Research Eyelink 1000 eye-tracking system with a sampling rate of 1,000 Hz. The materials were presented on a 21-inch CRT monitor (resolution: 1024 × 768 pixels; refresh rate: 150 Hz) connected to a Dell PC. Each sentence was displayed on a single line in Song 20-point font and the characters were shown in black (RGB: 0, 0, 0) on a gray background (RGB: 128, 128, 128). A chin rest and forehead rest were used to minimize head movement during the experiment. Participants were seated 58 centimeters away from the computer; at this distance, one character subtended a visual angle of approximately 0.7°. For each participant the viewing was binocular, but only the right eye was monitored.

Materials and design

Sixty-four overlapping ambiguous strings (ABC) were selected as the target items. The word frequency of the first words (AB) in the overlapping ambiguous string (M = 36.26 occurrences per million, SE = 11.39) was comparable to that of the second words (BC; M = 33.67 occurrences per million, SE = 9.21, $t(63) = 0.18$, $p = .860$). The stroke number was also matched between the first words (*M* = 15.50, *SE* = 4.30) and the second words (*M* = 14.30, *SE* = 4.06, $t(63) = 1.63$, $p = .106$). When the overlapping ambiguous strings (ABC) were presented in isolation (i.e., without any context), Chinese readers (as indicated by the results of another ten participants) segmented them as AB-C (*M* = .46, *SE* = .04, $t(63) = -0.97$, $p = .335$) or A-BC construction equally often (*M* = .54, *SE* = .04, $t(63) = 0.97$, $p = .335$).

Each overlapping ambiguous string was embedded into four sentences (see Table 1 for examples). All experimental sentences were composed of three parts: a prior context region (including all words preceding the overlapping ambiguous string), the overlapping ambiguous string region, and a post-target region (including all words following the overlapping ambiguous string). We manipulated whether the prior context provided syntactic information for the next words (i.e., the informative condition) or not (the neutral condition). For example, if given a preceding context of *尽职尽责的* (which means *conscientious*), a noun is needed; but if given the context of *急匆匆地* (which means *hurriedly*), a verb is needed. In contrast, for a neutral context such as *大家看到* (which means *it was noticed that*), prior context did not cause a strong preference for a noun or a verb. For the overlapping ambiguous strings used in this experiment, the first character was a 1-character verb, and the first two characters constituted a 2-character noun. We used a norming task to evaluate how effective the context is. To do so, we displayed the preceding part of the sentences to the left of the overlapping ambiguous string region to thirty-two participants who did not participate in the main experiment and asked them to write down their predicted words that they came up next. As shown in Table 2, 98% participants predicted a noun in the informative AB-C condition, and 94% participants predicted a verb in the informative A-BC condition. In contrast, participants did not show a preference for noun or verb when prior sentence context was neutral. In the neutral AB-C condition, 46% participants predicted a noun and 30% participants predicted a verb. And in the neutral A-BC condition, 38% participants predicted a noun and 35% participants predicted a verb. Even though readers could predict whether a noun or a verb should be presented at the overlapping ambiguous string region, they usually could not predict the exact word. The predictability of A or AB in the overlapping ambiguous string was close to zero (0.02), and did not differ between conditions.

In the informative context, the post-target region was always consistent with the segmentation that was supported by prior context. And in the neutral context, the post-target region provided disambiguating information regarding whether the first word (AB-C) or the second word (A-BC) segmentation was correct. Thus, the design was a 2 (context informativeness: informative vs. neutral) × 2 (segmentation type: AB-C vs. A-BC) within-participants design.

In the formal experiment, each participant read all of the overlapping ambiguous strings, but they only read each string once (in one of the four sentences). Sentence length was comparable in different conditions (19.86 characters for the informative AB-C condition, 19.92 characters for the informative A-BC condition, 19.75 characters for the neutral AB-C condition, 20.25 characters for the neutral A-BC condition; $F(3, 252) = 1.47$, $p = .223$). Twenty Chinese speakers from universities who did not participate in the eye tracking experiment were recruited to assess the plausibility of the sentences. They were assigned to one of four counterbalanced lists and were asked to rate the plausibility of each sentence on a 7-point scale (1 = very implausible, 7 = very plausible). The plausibility values did not significantly differ among conditions (5.3 for the informative AB-C condition, 5.3 for the informative A-BC condition, 5.1 for the neutral AB-C condition, 5.1 for the neutral A-BC condition; $F(3, 252) = 1.52$, $p = .211$). In order to ensure the effectiveness of the context manipulation, we presented each sentence up to (and including) the overlapping ambiguous string, and asked another twenty participants to segment the overlapping ambiguous string. The informative AB-C condition had a probability of AB-C segmentation of .95, indicating that participants segmented the overlapping ambiguous strings as AB-C more frequently than the chance level ($t(63) = 27.44$, $p < .001$); the informative A-BC condition had a probability of AB-C segmentation of .11, which indicated a significantly greater bias toward A-BC than the chance level ($t(63) = -16.15$, $p < .001$). In the two neutral conditions, readers segmented the overlapping ambiguous string more randomly, .59 and .56 for the neutral AB-C ($t(63) = 2.30$, $p = .023$) and the neutral A-BC condition ($t(63) = 1.09$, $p = .277$), respectively.

Procedure

When participants came into the lab, they were given the experimental instructions and a brief description of the apparatus. The eye tracker was calibrated at the beginning of the experiment and was calibrated again during the experiment as needed. A three-point calibration and validation procedure was used, and the maximal error of validation was below 0.5° in the visual angle. Each sentence appeared after participants fixated on a character-sized box at the location of the first character of each sentence. Next, each participant read ten sentences for practice, followed by 64 experimental sentences and 64 filler sentences in a random order. Participants were asked to read the sentences silently and to answer some comprehension questions following approximately one third of the sentences. After reading each sentence, they pressed a response button to start the next trial.

Results

The mean accuracy of the comprehension questions was 95%, indicating that the participants understood the sentences well. Since blinks can cause noises, trials in which participants made more than three blinks while reading the entire sentence or made one or more blinks on the target word were excluded from the analysis, resulting in a loss of 2.73% of the trials. Fixations with durations longer than 1,000 ms or shorter than 80 ms (approximately 1.55%) were also excluded from the analysis. We primarily analyzed the following eye movement measures in the overlapping ambiguous string region: (a) skipping rate (the probability that the overlapping ambiguous string region was skipped during the first-pass reading); (b) first-fixation duration (the duration of the first fixation on the overlapping ambiguous string region during the first-pass reading); (c) gaze duration (the summed duration of all of the first-pass fixations on the overlapping ambiguous string region before moving on to another word); (d) regression-out probability (the percentage of regressions made from the overlapping ambiguous string region to earlier areas before leaving the overlapping ambiguous string region in a forward direction); (e) regression-in probability (the percentage of regressions made back to the overlapping ambiguous string region after leaving it); (f) second-pass reading time (the sum of all fixations in the overlapping ambiguous region following the initial first-pass reading, including zero times when the overlapping ambiguous region is not fixated, see Clifton, Staub, & Rayner, 2007); (g) sentence reading time (the sum of all fixations on the sentence). Skipping rate and first-fixation duration reflect the early stage of processing, such as lexical access; gaze duration is influenced by both lexical access and integration process; and the other measures such as regression-out probability and regression-in probability reflect later processing, such as sentence integration or error correction (Duffy, Morris, & Rayner, 1988; Inhoff, 1984; Rayner, 1998).

Data were analyzed using *linear mixed-effects models* (LMMs) for continuous variables (e.g., first-fixation duration and gaze duration) and *generalized mixed-effects models* (GLMMs) for binary dependent variables (e.g., skipping rate, regression-out probability and regression-in probability). Context informativeness, segmentation type, and their interaction were entered as fixed effects, specifying the participants and items as crossed random effects, including intercepts and slopes (see Baayen, Davidson, & Bates, 2008 for methodology). In the case that a model failed to converge, we firstly removed slopes in the items. If the model still did not converge, we set the iteration number as 20,000. Then, the overfitting slopes in the random effects were removed (Corr > .90; Barr, 2013). The *lmer* function from the *lme4* package (Bates, Maechler, Bolker, & Walker, 2014) was used within the *R* Environment for Statistical Computing (R Development Core Team, 2016). We report regression coefficients (*b*s*,* which estimates the effect size and change in log odds for binary dependent variables), standard errors (*SE*s), t values (for durations), z values (for binary dependent variables), and corresponding p values. We estimated and reported the p-values for the effects by using the *summary* function from *lmerTest* package (Kuznetsova, Brockhoff, & Christensen, 2014). Under the circumstance of significant interaction, we conducted simple effect analyses using the function from *emmeans* package (Lenth, Singmann, Love, Buerkner, & Herve, 2018). Fixation duration measures were not log-transformed. Detailed eye movement measures are shown in Table 3, and fixed effects estimates from the LME models for all measures are shown in Table 4.

Skipping rate. The main effect of context informativeness did not reach significance (informative condition: $M = 0.04$, $SE = 0.01$; neutral condition: $M = 0.03$, $SE = 0.01$, $b = 0.12$, $SE = 0.12$, $z = 1.01$, $p = .315$). But we found that the skipping rates were significantly higher in the AB-C segmentation condition ($M = 0.05$, $SE = 0.01$) than in the A-BC segmentation condition ($M = 0.02$, $SE = 0.004$, $b = 0.34$, $SE = 0.12$, $z = 2.79$, $p = .005$). More importantly, the interaction between context informativeness and segmentation type was significant ($b = 0.25$, $SE = 0.12$, $z = 2.03$, $p = .042$). Simple effect analysis showed that when the prior context was informative, skipping rates were significantly higher in the AB-C segmentation condition than that in the A-BC segmentation condition ($b = 1.18$, $SE = 0.34$, $z = 3.74$, $p < .001$). But there was no significant difference between the AB-C and A-BC segmentation conditions when the prior context was neutral (*b* = 0.19, *SE* = 0.35, *z* = 0.52, *p* = .600).

We also analyzed skipping rate launched from different positions. When eye movements launched from the first character to the left of the overlapping ambiguous string, skipping rates were higher in the informative AB-C condition (*M* = .11, *SE* = .04) than that in the informative A-BC condition (*M* = .02, *SE* = .01). However, skipping rates were comparable between the neutral AB-C condition (*M* = .06, *SE* = .02) and the neutral A-BC condition (*M* = .06, *SE* = .02). Moreover, when eye movements launched from the second character and the third character to the left of the overlapping ambiguous string, skipping rates were comparable between the informative AB-C condition (2nd character: *M* = .04, *SE* = .02; 3rd character: *M* = .02, *SE* = .01) and the informative A-BC condition (2nd character: *M* = .03, *SE* = .01; 3rd character: *M* = .02, *SE* = .02). Thus, the above results regarding skipping rates mainly came from the skipping rates launched from the first character to the left of the overlapping ambiguous string. In this situation, readers had more chances to process the entire overlapping ambiguous string with parafoveal vision and skip this region.

First-fixation duration. The main effect of context informativeness did not reach significance (informative condition: *M* = 292 ms, *SE* = 3.26; neutral condition: *M* = 293 ms, *SE* = 3.52, *b* = -0.91, *SE* = 2.27, *t* = -0.40, *p* = .690). However, first-fixation durations were significantly shorter in the AB-C segmentation condition (*M* = 288 ms, *SE* = 3.20) than that in the A-BC segmentation condition (*M* = 298 ms, *SE* = 3.57, *b* = -5.04, *SE* = 2.27, *t* = -2.22, *p* = .027). Moreover, the interaction between context informativeness and segmentation type was significant (*b* = -10.23, *SE* = 2.27, *t* = -4.50,

$p < .001$). Specifically, when the prior context was informative, first-fixation durations were significantly shorter in the AB-C segmentation condition than that in the A-BC segmentation condition ($b = -30.54$, $SE = 6.42$, $t = -4.76$, $p < .001$). But no significant difference was found between the AB-C and A-BC segmentation conditions when the prior context was neutral ($b = 10.38$, $SE = 6.44$, $t = 1.61$, $p = .110$).

The patterns of skipping rate and first-fixation duration are not consistent with the predictions of the two-stage hypothesis. Under this hypothesis, readers would not use context information immediately, and the sentence effect exerts itself at a later stage to help readers with checking whether initial segmentation was correct or not and integrating inputs to current text representation. As a result, no significant differences between the informative context and neutral context should be observed for the skipping rate and first-fixation duration. Nevertheless, we found that when the prior context provided information about AB-C that was consistent with the left-side word advantage caused by reading direction, skipping rates were higher and first-fixation durations were shorter compared to the inconsistent condition. And without informative context, no significant difference was found between the AB-C and A-BC segmentation conditions. These patterns are easily accounted for by the immediate hypothesis and the partial processing hypothesis. In the informative condition, readers segmented the overlapping ambiguous strings by using context information immediately; thus, there were fewer processing difficulties when context information was consistent with the left-side word advantage introduced by reading direction. In contrast, when readers had no context information to help them with segmentation in the neutral condition, they segmented the ambiguous region according to the left-side word advantage caused by reading direction.

If readers do not use context information immediately but use sentence context at the integration stage, they should try to integrate words with the context, which resulted in longer times and fewer skipping rates when the prior context provided information. To test this prediction, we conducted the following planed contrasts for skipping rate and first-fixation duration. For skipping rates, the readers skipped the overlapping ambiguous string region more often when the prior context provided information than when context was neutral in the AB-C segmentation condition (b = 0.75, SE = 0.30, z = 2.52, p = .011); while in the A-BC segmentation condition, no difference was found between the informative and neutral context conditions (b = -0.25, SE = 0.39, z = 0.60, p = .546). Similarly, in the AB-C segmentation condition, first-fixation durations were significantly shorter when the prior context was informative than when the context was neutral (b = -22.27, SE = 6.44, t = -3.46, $p < .001$). In the A-BC segmentation condition, first-fixation durations were longer when the prior context was informative than when prior context was neutral (b = 18.65, SE = 6.42, t = 2.91, $p < .001$). These results suggested that readers used prior context information immediately when they processed the overlapping ambiguous string.

Gaze duration. Gaze durations in the informative condition (M = 492 ms, SE = 9.44) were significantly shorter than those in the neutral condition (M = 524 ms, SE = 10.02, b = -17.49, SE = 6.30, t = -2.78, p = .006). Additionally, gaze durations were shorter in the AB-C segmentation condition (M = 469 ms, SE = 8.69) than that in the

A-BC segmentation condition (*M* = 547 ms, *SE* = 10.57, *b* = -40.10, *SE* = 6.30, *t* = -6.37, *p* < .001). More importantly, there was also a significant interaction between context informativeness and segmentation type (*b* = -30.12, *SE* = 6.30, *t* = -4.78, *p* < .001). Specifically, when the prior context was informative, readers had longer gaze durations in the A-BC segmentation condition than those in the AB-C segmentation condition (*b* = -140.44, *SE* = 17.78, *t* = -7.90, *p* < .001); and no significant difference was observed between AB-C and A-BC segmentation types in the neutral context condition (*b* = -19.95, *SE* = 17.78, *t* = -1.12, *p* = .260).

Regression-out probability. In the informative condition (*M* = 0.16, *SE* = 0.01), readers made fewer regressions out of the overlapping ambiguous string region than those in the neutral condition (*M* = 0.18, *SE* = 0.01, *b* = -0.13, *SE* = 0.06, *z* = -2.17, *p* = .030). In addition, there were fewer regression-out probabilities in the AB-C segmentation condition (*M* =0.14, *SE* = 0.01) than in the A-BC segmentation condition (*M* = 0.21, *SE* = 0.01, *b* = -0.30, *SE* = 0.06, *z* = -5.16, *p* < .001). And there was also a significant interaction between context informativeness and segmentation type (*b* = -0.30, *SE* = 0.06, *z* = -5.12, *p* < .001). Specifically, when the prior context was informative, there were fewer regression-out probabilities in the AB-C segmentation condition than those in the A-BC segmentation condition (*b* = -1.19, *SE* = 0.17, *z* = -6.86, *p* < .001); no significant difference was observed between the AB-C and A-BC segmentation types in the neutral context condition (*b* < 0.001, *SE* = 0.15, *z* = 0.03, p = .980).

Regression-in probability. For regression-in probabilities, the main effects of context informativeness and segmentation type were both significant. In the informative condition (M = 0.42, SE = 0.01), readers made fewer regressions to the overlapping ambiguous string region than in the neutral condition (M = 0.54, SE = 0.01, b = -0.30, SE = 0.04, z = -6.76, p < .001). Regression-in probabilities were higher in the A-BC segmentation condition (M = 0.52, SE = 0.01) than in the AB-C segmentation condition (M = 0.44, SE = 0.01, b = -0.19, SE = 0.07, z = -2.78, p = .006). No significant interaction between context informativeness and segmentation type was found (b = 0.05, SE = 0.04, z = 1.15, p = .250).

Second-pass reading time. The main effects of context informativeness and segmentation type were both significant. Second-pass reading times were significantly shorter in the informative condition (M = 342 ms, SE = 17.54) than that in the neutral condition (M = 566 ms, SE = 22.57, b = -111.63, SE = 17.16, t = -6.51, p < .001). Additionally, second-pass reading times were shorter in the AB-C segmentation condition (M = 356 ms, SE = 16.91) than in the A-BC segmentation condition (M = 551 ms, SE = 23.13, b = -95.24, SE = 17.02, t = -5.60, p < .001). The interaction between the context informativeness and segmentation type was not significant (b = 14.23, SE = 17.56, t = 0.81, p = .422).

The two-stage hypothesis and the immediate hypothesis have trouble accounting for the full pattern found in the results. Even though the two-stage hypothesis is consistent with the findings that readers had longer gaze durations and made more regressions out of the overlapping ambiguous string region when the context information was consistent with A-BC segmentation, it predicted no difference between the informative and neutral context conditions for the skipping rate and first-fixation duration because sentence context does not exert its effect immediately when readers segment the overlapping ambiguous strings, which the immediate hypothesis accounted for. But evidence of regressions in the informative condition was inconsistent with the immediate hypothesis, since the sentence context information was used to segment the overlapping ambiguous strings immediately and no regressions should be made under this hypothesis.

Current results are easily accounted for by the partial processing hypothesis. Since readers did not fully use the context information, some of the sentence contexts did not override the segmentation based on left-side word advantage which was caused by reading direction. Thus, the readers used context information to check and correct the initial segmentation. When the prior context information conflicted with the left-side word advantage, there were more processing costs during the integration stage, which was reflected by longer gaze durations and higher regression-out probabilities. Moreover, the readers made fewer regressions into the overlapping ambiguous string region in the informative condition than in the neutral condition, suggesting that the sentence context also played a role in the later stages of processing.

Sentence reading time. The main effects of context informativeness and segmentation type were both significant. Sentence reading times were significantly shorter in the informative condition (M = 2,651 ms, SE = 27.89) than that in the neutral condition (M = 2,779 ms, SE = 30.95, b = -72.76, SE = 18.78, t = -3.87, p < .001). Additionally, the sentence reading times were shorter in the AB-C segmentation condition (M = 2,654 ms, SE = 27.56) than in the A-BC segmentation condition (M = 2,776 ms, SE = 31.42, b = -70.60, SE = 18.80, t = -3.76, p < .001). The interaction between the context informativeness and segmentation type was not significant (b = -6.21, SE = 18.76, t = 0.33, p = .741). Thus, sentence reading times reflected the benefit of sentence context and a left-side word advantage.

General Discussion

In the current study, we investigated how the prior context affects the processing of overlapping ambiguous strings while reading Chinese using eye tracking technology. We manipulated the informativeness of the prior context and segmentation type.

Summary of results. For skipping rate and first-fixation duration, we found that when the prior context supported the AB-C construction, the skipping rates were higher and first-fixation durations were shorter than when the segmentation type was A-BC. On the contrary, when the prior context was neutral and did not support any segmentation type, no significant difference was found between AB-C and A-BC segmentation types for skipping rate and first-fixation duration. Furthermore, regression-out probabilities were higher and gaze duration were longer in the informative A-BC condition than in the informative AB-C condition, while no significant difference was found in the processing of AB-C or A-BC segmentation types when the prior context was neutral. Additionally, even when the prior context provided segmentation-related information, readers still made regressions into the overlapping ambiguous string region. These results supported a partial processing hypothesis, which assumes that the readers used sentence context information immediately, but they did not use sentence context information fully.

Left-side word advantage. The results of the current study showed a clear pattern that Chinese readers prefer to segment the overlapping ambiguous strings as AB-C when other factors (such as word frequency) are equal. In the informative conditions, all of the eye movement measures showed advantages of AB-C construction over the A-BC construction. Reading times were shorter, skipping rates were higher, and regression-out and regression-in probabilities were fewer. In the neutral conditions, regression-in probabilities were fewer in the AB-C condition than in the A-BC condition. These results suggest that Chinese readers prefer to group the two characters on the left side of the overlapping ambiguous string as a word when word frequencies do not provide any bias. If the final correct segmentation is different from that, readers need to spend more time correcting the segmentation.

Why do Chinese readers have a left-side word advantage toward the overlapping ambiguous strings? A Chinese word segmentation and recognition model proposed by Li, Rayner, and Cave (2009) might give some hints. Li et al.'s model suggested that the characters in the perceptual span are processed in parallel, and that all of the words constituted by these characters are activated and compete for a single winner. When processing the overlapping ambiguous string ABC, the words A, AB, and BC are all activated. During the competition, the word AB has some advantages over word A, since word AB receives excitatory feedforward links from two character units (A and B), but the word A only received excitatory feedforward links from one character unit

(A). In addition, the word AB also has advantages over the word BC, because readers' eyes move from left to right and the characters on the left are closer to foveal than the characters on the right before the eyes fixating on the overlapping ambiguous string. Therefore, activities of the character units on the left (e.g., character A) increase earlier than the character unit on the right (e.g., character C). As a result, the activation of word AB increases faster than the activation of word BC. Thus, the word AB has a better chance of winning the competition during natural reading. As a result, the word AB is more likely to be segmented as a word. Previous studies provided evidence that Chinese readers prefer to process a longer word as a whole even though part of its constituting character(s) constitute another word (Yang, Staub, Li, Wang, & Rayner, 2012; Zhou & Li, under review). Yang et al. (2012) found that whether the first character of a two-character compound word was plausible within its sentence context did not influence the reading times on the two-character word. These results suggested that Chinese readers tend to process two-character Chinese words as a whole rather than on a character-by-character basis. Using a similar logic, Zhou and Li (under review) found that Chinese readers process a three-character word as a whole although the first two characters of that words could constitute another word.

It should be noted that although the words on the left have some advantages, it does not mean that the word on the left has an absolute priority. If the word frequencies of the right word are high enough, the word on the right can be segmented as a word, and the character in the middle of the overlapping ambiguous string can be assigned to the word on the right. This has been shown by Ma et al. (2014). In their study, when the word BC had a higher frequency than the word AB, readers were more likely to segment the overlapping ambiguous strings as A-BC. Therefore, it seems that the word segmentation outcome is influenced by multiple factors such as reading direction, word frequency, and sentence context.

The left-side word advantage is consistent with a left-branching preference found by Pollatsek et al. (2010). In their study, readers showed a bias toward a left-branching structural interpretation for ambiguous trimorphemic words while reading English. It seems that in the face of strings with structural and semantic ambiguity, readers are more inclined to show a left-side word advantage or left-branching preference which might be universal across languages.

The immediate effect of prior context. The results suggest that Chinese readers use prior sentence context information immediately when they process the overlapping ambiguous strings, reflected by skipping rate and first-fixation duration. Traditionally, different eye movement measures are thought to reflect different underlying cognitive processes during reading (Rayner, 1998, 2009): skipping rate and first-fixation duration are mainly influenced by the early stages of processing, such as lexical access; gaze duration is influenced by both lexical access and at least some of the integration process (Duffy, Morris, & Rayner, 1988; Inhoff, 1984); whereas the probability of making a leftward saccade from the word (or *regression out*) reflects the late stages of processing, such as word integration or error correction (Clifton, Staub, & Rayner, 2007). In the present study, we found that the skipping rate and first fixation durations were all affected by prior context. These results suggested that readers use context information immediately to segment the overlapping ambiguous strings.

How does prior sentence context affect word segmentation? Constraint-based models can shed some light on this question. The constraint-based models (e.g., MacDonald et al., 1994; McRae et al., 1998; Spivey & Tanenhaus, 1998; Taraban & McClelland, 1988; Trueswell, 1996; Trueswell et al., 1994; Tyler & Marslen-Wilson, 1977) state that syntactic ambiguity resolution is a continuous and constraint-satisfaction process. All relevant resources of information are immediately integrated during parsing and interpretation, where alternative interpretations are computed and compete with each other until one achieves the criterion of activation. When there is inconsistent biasing information, processing difficulties occur. Thus, the prior context can exert its effect immediately as a kind of biasing information, and the left-side word advantage caused by reading direction is another kind of biasing information. During reading, readers usually immediately drew on the context information to generate syntactic expectations for next words. In the informative AB-C condition, a two-character noun was expected, hence readers preferred to segment the overlapping ambiguous string as AB-C. This is consistent with the left-side word advantage introduced by reading direction, and thus evidence from these two sources are consistent. In this situation, readers will be easier to determine how to segment the overlapping ambiguous string. In contrast, in the informative A-BC condition, a one-character verb was expected, and thus the A-BC construction was preferred, which is not consistent with left-side word advantage caused by reading direction. In this situation, readers received contradictory evidence from different sources, and this will cause difficulty for word segmentation, resulting in longer first-fixation durations and lower skipping rates. For neutral conditions, readers had no sentence context information to help them with the initial segmentation in either segmentation types. In this situation, word segmentation is mainly determined by left-side word advantage caused by reading direction. Thus, readers prefer to segment the overlapping ambiguous string as AB-C. This can explain why no significant difference was found for skipping rate and first-fixation duration in the neutral condition.

Current results are consistent with the study which investigated how structural analyses of ambiguous trimorphemic words are influenced by sentence context using a cross-modal priming experiment (de Almeida & Libben, 2005). They found that when the ambiguous trimorphemic words were presented in isolation, there was a bias toward right-branching structure. More importantly, when such words were presented in strongly constraining sentence contexts, these preferred parses were modified online to be consistent with the sentence context, providing evidence for the effect of sentence context on the interpretation of ambiguous trimorphemic words.

However, the finding that the prior context immediately affects word segmentation is different from the study of ambiguous trimorphemic words in English conducted by Pollatsek et al. (2010). In their experiment, preceding context only influenced go-past times rather than gaze durations on the overlapping ambiguous string regions. They concluded that the preceding context does not affect the initial interpretation of ambiguous trimorphemic words, and readers use context information to correct the initial interpretation at a later stage. It should be noted that the nature of the overlapping ambiguous strings in Chinese is different from the nature of the ambiguous trimorphemic words. Due to interword spaces, the ambiguous trimorphemic word such as UNLOCKABLE is viewed as an independent word, while Chinese overlapping ambiguous string is a continuous string during parafoveal processing. For the latter situation, readers are more compelled to make use of the preceding information to segment the ambiguous string so as to comprehend text successfully. Additionally, the preceding context in the study of Pollatsek et al. (2010) might be less constraining than that in the current study.

The limited role of prior sentence context. The results of the current study showed that Chinese readers do not use prior context information fully when they segment the overlapping ambiguous strings. When prior context was informative, readers were provided with segmentation-related information. Hence, if readers utilize context information fully, as predicted by the immediate hypothesis, readers should not make regressions back to the overlapping ambiguous string regions when they read later texts when prior context is informative. However, that is not quite the case. In the informative condition, readers still made regressions to the overlapping ambiguous string region even when the prior sentence context is informative. And there are differences between the informative AB-C and the informative A-BC conditions.

The finding that readers did not use prior context information fully to segment the overlapping ambiguous strings during first-pass reading is similar to the assumptions of the good-enough approach to language comprehension (Ferreira et al., 2002). According to the good-enough approach, readers sometimes only process text to get a parse of input that is good-enough to react to the current task. In the current study, readers had no informative preceding context in about half of the trials. And readers would encounter disambiguating materials after the overlapping ambiguous string region so that they could resolve the ambiguity in all conditions. It seems that the current task did not put strict enough demands on readers for them to use prior context information fully to segment the overlapping ambiguous string. In the current study, although readers do not use sentence context information fully during first-pass reading, there was evidence that readers tried their best to segment words correctly. The probabilities of making regressions to the overlapping ambiguous strings were high. This might reflect that after initial segmentation performed by good-enough processing, readers conducted a selective reanalysis (Frazier & Rayner, 1982) during which they made regressions into the overlapping ambiguous string region to collect information for correcting initial segmentation or ensure they had made final segmentation correctly.

Implications for readability. Readers took shorter times to read the sentence when the sentence had informative context or the writing manner was consistent with our reading direction. Thus, in order to improve the readability of text, prior context and the left-side word advantage introduced by reading direction should be considered. For texts where there are potential ambiguities, authors can provide informative preceding contexts to help readers with comprehension. If not, authors can organize text in a manner consistent with reading direction.

Conclusions. In summary, the results of the current study provide strong evidence for the role of prior context in word segmentation of overlapping ambiguous strings during Chinese reading. Readers use prior context information to help them with segmentation immediately. However, readers do not use context information fully, and in some trials, prior context information cannot override the segmentation based on the left-side word advantage caused by reading direction. There is a left-side word advantage when Chinese readers segment the overlapping ambiguous strings. These findings are important in understanding how Chinese readers segment words without the aid of interword spaces while reading Chinese.

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Table 1

Examples of stimuli in the experiment

Condition	Example
Informative, seg. AB-C	尽职尽责的**领队-长**了一身痱子仍在烈日下坚持着。 (The dutiful and responsible *leader suffering from* prickly heat still persevered in the hot sun.)
Informative, seg. A-BC	志愿者急匆匆地**领-队长**去拿比赛器材和道具。 (The volunteers hurriedly *guided leaders* to get the competition equipment and props.)
Neutral, seg. AB-C	大家看到**领队-长**了一身痱子仍在坚持工作。 (It was noticed that the *leader suffering from* prickly heat still insisted on working.)
Neutral, seg. A-BC	大家看到**领-队长**进场的志愿者是个外国小伙儿。 (It was noticed that the *leaders* were *guided* to the arena by a volunteer who was a foreign boy.)

Note: The overlapping ambiguous strings are in bold, and the "-" symbols are added in the figure for the illustration purposes, but the characters were not bolded or segmented in the experiment.

Table 2

Probabilities of the word type following the prior contexts in different conditions

	Informative		Neutral	
Word type	AB-C	A-BC	AB-C	A-BC
Noun	.98	.02	.46	.38
Verb	.02	.94	.30	.35
Pronoun	.00	.00	.17	.18
Others (including adjective and adverb)	.00	.04	.07	.08

Table 3

Eye movement measures in the overlapping ambiguous string region

Measure	Informative		Neutral	
	seg AB-C	seg A-BC	seg AB-C	seg A-BC
Skipping rate	0.06(0.01)	0.02(0.01)	0.03(0.01)	0.03(0.01)
First-fixation duration	277(4)	307(5)	299(5)	288(5)
Gaze duration	422(11)	560(15)	516(13)	533(15)
Regression-out probability	.09(.01)	.24(.01)	.18(.02)	.18(.02)
Regression-in probability	.39(.02)	.45(.02)	.49(.02)	.60(.02)
Second-pass reading time	258(18)	427(30)	456(28)	677(35)
Sentence reading time	2595(37)	2720(42)	2725(41)	2847(47)

Note: First-fixation duration, gaze duration and sentence reading time were measured in milliseconds. Standard errors are given in parentheses.

Table 4

Results of the Linear Mixed-Effects Models for fixation duration measures and results of the Generalized Linear Mixed-Effects Models for fixation probability measures. Significant effects are indicated in bold.

Measure	Fixed effect	Estimate	*SE*	*t/z*	*p*
Skipping rate	Context informativeness	0.12	0.12	1.01	.315
	Segmentation type	**0.34**	**0.12**	**2.79**	**.005**
	Context informativeness × Segmentation type	**0.25**	**0.12**	**2.03**	**.042**
First-fixation duration	Context informativeness	-0.91	2.27	-0.40	.690
	Segmentation type	**-5.04**	**2.27**	**-2.22**	**.027**
	Context informativeness × Segmentation type	**-10.23**	**2.27**	**-4.50**	**<.001**
Gaze duration	Context informativeness	**-17.49**	**6.30**	**-2.78**	**.006**
	Segmentation type	**-40.10**	**6.30**	**-6.37**	**<.001**
	Context informativeness × Segmentation type	**-30.12**	**6.30**	**-4.78**	**<.001**
Regression-out probability	Context informativeness	**-0.13**	**0.06**	**-2.17**	**.030**
	Segmentation type	**-0.30**	**0.06**	**-5.16**	**<.001**
	Context informativeness × Segmentation type	**-0.30**	**0.06**	**-5.12**	**<.001**
Regression-in probability	Context informativeness	**-0.30**	**0.04**	**-6.76**	**<.001**
	Segmentation type	**-0.19**	**0.07**	**-2.78**	**.006**
	Context informativeness × Segmentation type	0.05	0.04	1.15	.250
Second-pass reading time	Context informativeness	**-111.63**	**17.16**	**-6.51**	**<.001**
	Segmentation type	**-95.24**	**17.02**	**-5.60**	**<.001**
	Context informativeness × Segmentation type	14.23	17.56	0.81	.422
Sentence reading time	Context informativeness	**-72.76**	**18.78**	**-3.87**	**<.001**
	Segmentation type	**-70.60**	**18.80**	**-3.76**	**<.001**
	Context informativeness × Segmentation type	-6.21	18.76	0.33	.741