Contextual Constraint and Preview Time Modulate the Semantic Preview Effect: Evidence from Chinese Sentence Reading

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Abstract

Word recognition in sentence reading is influenced by information from both preview and context. Recently, semantic preview effect (SPE) was observed being modulated by the constraint of context, indicating that context might accelerate the processing of semantically related preview words. Besides, SPE was found to depend on preview time, which suggests SPE may change with different processing stages of preview words. Therefore it raises the question of whether preview-time-dependent SPE would be modulated by contextual constraint. In the current study, we investigated the impact of contextual constraint on SPE in Chinese reading, but also examined its dependency on preview time. The preview word and the target word were identical, semantically related, or unrelated to the target word. The results showed a significant three-way interaction: The SPE depended on contextual constraint and preview time. In separate analyses for low and high contextual constraint of target words, the SPE significantly decreased with an increase in preview duration when the target word was of low constraint in the sentence. The effect was numerically in the same direction, but weaker and statistically non-significant when the target word was highly constrained in the sentence. The results indicate that word processing in sentences is a dynamic process of integrating information from both preview (bottom up) and context (top down).

Keywords: semantic preview benefit, contextual constraint, word process, reading

Reading requires the integration of words into a coherent representation. Previous studies consistently showed that both the information from context and from preview can influence the processing of words, but how they interact during online reading is not understood very well. There is general agreement that during natural reading word recognition starts already before the word is fixated while it is still located in the parafoveal region. Much of what is known about parafoveal processing has been learned from eye-tracking experiments using the boundary paradigm, which was developed by Keith Rayner (Rayner, 1975). In this paradigm, a target word in a sentence is masked during preview and unmasked once it is fixated. By varying the information in the preview, one can study what kind of information is extracted parafoveally. For example, the target word "chair" could be masked during preview either by itself (chair) or by an unrelated word (e.g., light). The classic finding observed with this paradigm is the preview effect: Fixations are significantly shorter after valid than after invalid previews. The boundary paradigm has greatly enhanced research on parafoveal reading and our understanding of the fundamental processes contributing to it. Using the boundary paradigm, a great deal of studies have explored what kind of information readers can obtain from parafovea. Preview information about length, shape, and phonology of a parafoveal word shorten a subsequent fixation duration (e.g., Schotter, Angele, & Rayner, 2012, for a review). As far as preview of semantic information is concerned, evidence has been consistent for Chinese (Yan, Richter, Shu, & Kliegl, 2009; Yang, Wang, Tong, & Rayner, 2012), German (Hohenstein & Kliegl, 2014; Hohenstein, Laubrock, & Kliegl, 2010), and Korean (Kim, Radach, & Vorstius, 2012) and absent in English in early studies (Balota, Pollatsek, & Rayner, 1985; Drieghe, Rayner, &

Pollatsek, 2005; Rayner, Schotter, & Drieghe 2014), but now there is progress to understand the conditions under which semantic preview benefit is obtained for English sentences (Schotter, 2013; Schotter, Lee, Reidermann, & Rayner, 2015). Semantic information cannot only be extracted from the parafovea but can also be integrated with context (Yang, Staub, Li, Wang, & Rayner, 2012; Yang, et al., 2012; Li, Niefind, Wang, Sommer, & Dimigen, 2015; Schotter & Jia, 2016; Veldre & Andrews; 2016).

Recently, the preview effect was found to increase with the processing time of the preview word (e.g., Yan, Risse, et al., 2012; Yan, 2015; Hohenstein & Kliegl, 2014; Marx, Hawelka, Schuster, & Hutzler, 2016), probably because longer preview processing time leads to more congruent parafoveal information obtained from identical preview and more incongruent parafoveal information obtained from masking preview (Yan, 2015). By using the fixation duration on the pre-target word as a covariate, Yan, et al. (2012) found that the semantic preview benefit from a preview word, which was not congruent in the sentence but semantically related to the word later seen in foveal vision, was larger for short preview durations and completely vanished with increasing preview durations. This indicates facilitation from processing of the related meaning that appears early during processing of the preview, but interference from processing of incongruent information that appears with ongoing processing of the preview. Therefore, during the processing of words in sentences, the influence from preview may unfold over multiple processing stages with multiple effects.

Previous studies have suggested that during reading of text, information of context and preview information is integrated to complete the reading process. The interaction of context and low-level preview information (e.g., length, orthography) is well documented.

For example, the size of the preview effect of word length or word orthography is larger when the word is highly expected given the sentence context than when it is not expected (e.g. Juhasz, White, Liversedge, & Rayner, 2008; Balota, Pollatsek, & Rayner, 1985). However, only a few studies have explored how context interacts with high-level preview information such as semantically related previews (Balota et al., 1985; Schotter et al., 2015). With a manipulation of contextual constraint, Schotter et al. (2015) showed that the semantic preview effect (SPE) is modulated by contextual constraint on the target word. Specifically SPE was observed in high-constraint sentences, but not in low-constraint sentences. Since sentence constraint generates expectations about what kinds of words are likely to appear, the results implied that SPE obtained in the high-constraint sentences may be due to earlier access to semantic information of the semantically related preview words.

Given that the SPE was influenced by the contextual constraint of the sentence (Schotter et al., 2015), there is the question whether the preview-time-dependent SPE (Yan et al., 2012) is modulated by sources relating to the context in a sentence. If it does, we obtain information about how top-down and bottom-up processes interact during reading of sentences. Therefore, in the present study we examined how SPE is modulated by preview time as well as by contextual constraint in reading Chinese sentences. Given the stability of the SPE in reading Chinese, we should be in a good position to demonstrate such modulation.

In the present study, the first part of the sentence (from the beginning of the sentence to the third character to the left of the target word) was varied to make the target word of high constraint or of low constraint in the sentence. Note that the amount of constraint of low-constraint sentences in our experiment (averaged 28%) was higher than those of

low-constraint sentences used in previous studies (e.g. Yan et al., 2009, averaged 5%), because we needed to match at least two words before the target word between the two constraint conditions to ensure that there was no difference in foveal word during parafoveal processing. The semantic relationship between the preview word and the target word was manipulated such that the preview words were identical, semantically related or unrelated to the target word. We were particularly interested in the following questions: Does the preview-time-dependent SPE change under different conditions of contextual constraint? According to the results of Schotter et al. (2015) and Yan, Risse et al. (2012), the semantic preview benefit should be modulated by both the preview time and the contextual constraint on the target word in the sentence. Specifically, when the target word was of low constraint in the sentence, we expected to replicate the findings of Yan et al. (2012) that the semantic preview benefit was large for short preview times and decreased with an increase of preview time. In a sentence with a highly constrained target word, the pre-activation of the target word is likely to accelerate the processing of a semantically related word, thus we expected to see an earlier shift of SPE from semantic preview benefit to semantic preview cost. The context may exert its early influence by modulating the preview effect during the processing of words in reading.

Method

Participants

Sixty undergraduate students from South China Normal University with normal or corrected to normal vision participated the experiment. They were native speakers of Chinese.

Materials

Eighty-four single-character words and their semantically related and unrelated words were chosen as targets and previews. We used single-character words as targets rather than characters of multiple-character words because a single-character word represents an independent meaning unit in the sentence and was expected to yield a stronger signal of the preview effect based on the semantic relationship between previews and targets. Targets and previews were embedded in 84 pairs of experimental sentences each comprising 15 to 20 characters. Targets were located in the middle of the sentence with at least 5 characters ahead or following; there was no punctuation until the end of the sentence. An example sentence and its English translation is shown in Figure 1.

----------Figure 1 about here----------

Targets and previews were matched on word frequency and number of strokes. The frequencies for the target, related preview, and unrelated preview averaged 356 (SD = 371), 346(SD = 397), and 349 (SD = 357) per million, $F = .089$，$p > .9$. The number of strokes averaged 8.4 (SD = 3.1), 8.7 (SD = 2.9), and 8.6 (SD = 2.6) for these conditions, $F = .787$，$p > .4$.

Sentences were presented using the eye-movement contingent boundary technique (Rayner, 1975). Six counterbalanced material sets were created, each containing 84 experimental sentences. Each condition of the experimental sentences appeared once across the six sets.

Rating Studies

Sixteen participants rated the semantic relatedness between targets and previews on a 5-point scale (1 = highly unrelated; 5 = highly related). Semantic relatedness for the related preview words (M = 4.0, SD = .6) were significantly higher than the unrelated preview words (M = 1.5, SD = .5), t (83) = 25.4.

The degree of constraint was determined by participants completing each sentence pair (from the beginning of the sentence up to but not including the target word) with "the first word that comes to mind". 84 sentence pairs were divided into two lists so that the two sentence contexts containing the same target word did not appear in the same list. 100 students were randomly assigned to one of these lists. The cloze probability of high constraint sentences (M = .87, SD = .12) was significantly higher than that of low constraint sentences (M = .28, SD = .10), t (83) = 34.08.

For an assessment of plausibility, 48 participants rated the plausibility of the target word, related and unrelated preview word within each sentence context from the beginning of the sentence up to (and including) the target word or preview words on a 5-point scale (1 = highly implausible; 5 = highly plausible). Plausibility was significantly higher for target words in high constraint sentences (M = 4.2, SD = 0.6) than in low constraint sentences (M = 4.0, SD = 0.7), t (83) = 2.3. There was no significant difference between related (M = 2.2, SD = 0.6) and unrelated (M = 2.0, SD = 1.1) preview conditions in high constraint sentences, t (83) = 1.5, and no significant difference between related (M = 2.1, SD = 0.7) and unrelated (M = 2.2, SD = 1.1) preview conditions in low constraint sentences, t (83) = 0.9.

Apparatus

Eye movements were recorded with an SR Eyelink 1000 eye-tracking system at a rate of 1,000 HZ. We monitored movements of the right eye, although viewing was binocular. Stimuli were displayed on a Dell 19-in SVGA monitor with a refresh rate of 150 Hz. It took at most 10 ms to complete the display change. Each character was printed in simple Song font. The size of each character was 1.0 *1.0 cm, with 0.5 cm between individual characters. The participant's eyes were 57 cm away from the monitor. Each character subtended approximately 1 degree of visual angle with 0.5 degree of visual angle space between characters. Thus, each character with the space before and after subtended approximately 2 degree of visual angle, thereby maximizing the possibility that the target character was located in the parafovea when the pre-target character was fixated.

Procedure

Participants were calibrated with a 3-point procedure. They were instructed to read each sentence carefully for comprehension. Following five initial practice sentences, each participant read 84 experimental and 66 filler sentences in a random order. One-third of the sentences was followed by a true–false comprehension question. The experiment lasted about 30 minutes.

Data Analysis

Comprehension accuracy was 92%. The primary dependent variables were first fixation duration (FFD; the amount of time that the eyes initially fixate on the word, regardless of the number of fixations on the word) and gaze duration (GD; the sum of all fixations on a character prior to moving to another character) for characters n – 1 through character n + 1 (relative to the target character n) as a function of type of context and type of

preview. Fixations shorter than 60ms or longer than 600ms were eliminated from the analyses. Trials in which the display change occurred during a fixation were excluded. In total, 7% of the data were lost.

Statistical inferences were based on linear mixed models (LMMs) using the *lme4* package (Bates, Mächler, Bolker, & Walker, 2015; version 1.1-8) in the R environment for statistical computing and visualization (R Core Team, 2014). Aside from fixed effects and interactions relating to context, preview condition, and preview duration, LMMs included variance components for intercepts for items and for subjects, and variance components for fixed effects and correlation parameters.

To examine the contextual constraint influence on the semantic preview effect, the fixed factors included in the model were contextual constraint (high vs. low) and preview type (identical, semantically related, and semantically unrelated). For the LMM of fixation durations on the target region, we also included the linear trend of log of single fixation duration (SFD) on the pre-target region as a fixed effect. Analyses using preview SFD as covariate yielded the clearest dissociation of effects, possibly because single-fixation cases carry few mislocated fixations and are reliable indicators of successful parafoveal word segmentation (Yan et al., 2012). The effects of preview type were specified as two contrasts for estimates of an identical preview effect (unrelated vs. identical preview) and a semantic preview effect (unrelated vs. related preview).

For fixed effects, we report t-values larger than 2 as significant; these effects were also significant according to confidence intervals based on deviance profiles, using *lme4*'s profile function, which are based on much weaker assumptions than the Wald tests (Bates et

al., 2015). All reported LMM results are based on log-transformed durations, because analyses of model residuals strongly suggested the need for a log transformation of dependent variables to meet the normal-distribution assumption. Analyses for untransformed and log-transformed durations yielded the same pattern of significance. Figures show partial effects using the *remef* function provided by Hohenstein and Kliegl (2014). All analyses mentioned above are provided in the R scripts at the website (http://read.psych.uni-potsdam.de/pmr2/).

Results

Means and standard deviations of eye-movement measures from pre-target character N-1 to post-target character N+1 are shown in Table 1, Table 2, and Table 3.We report separate analyses of FFD and GD for each of the three characters.

Pre-target Character

The constraint effect was significant (GD: $b = 0.028$, $SE = 0.014$, $t = 2.0$). Reading times on the pre-target character were longer in low constraint condition than in high constraint condition. There was no significant difference between preview conditions, that is we did not find any significant prafoveal on foveal effect on the pre-target character.

----------Table 1 about here----------

Target Character

There was a main effect of constraint (FFD: b = 0.034, SE = 0.013, t = 2.6; GD: b = 0.043, SE = 0.014, t = 2.9; Skip: b = 0.1225, SE = 0.0614, t = 2.0). Reading times on the target character were longer in low constraint condition than in high constraint condition.

----------Table 2 about here----------

Semantic preview effect. With FFD on the target character as dependent variable, we found a significant three-way interaction of preview condition, contextual constraint, and pre-target single fixation duration (b = 0.001, SE = 0.001, t = 2.8) (Figure 2). Post-hoc analysis showed that the interaction between SPE and preview duration was significant in the low-constraint condition (b = 0.002, SE = 0.001, t = 2.8). SPE was only significant with short previews (<=222ms, 156 observations, b = 0.249, SE = 0.067, t = 3.7), reading times on the target character were longer in unrelated preview condition than in semantically related preview condition. However, such effect was not significant with long previews (>222ms, 151 observations, b = 0.021, SE = 0.072, t = 0.3). The result is in line with findings of Yan et al. (2012) (please see the results of Yan et al., 2012 in Figure 3) and suggests that facilitation from semantic processing of preview disappeared with accumulation of incongruent information in preview. In the high-constraint condition, however, there was not a significant SPE (b = 0.015, SE = 0.048, t = 0.3) or an interaction of SPE with preview time (b = 0.001, SE = 0.001, t = 1.3).

----------Figure 2 about here----------

----------Figure 3 about here----------

As shown in Figure 4, with GD as dependent variable, we still found a three-way interaction of preview condition, contextual constraint, and pre-target single fixation duration (b = 0.002, SE = 0.001, t = 3.2) (Figure 4). Post-hoc analysis showed that the interaction between SPE and preview duration was significant only in the low-constraint condition (b = 0.002, SE = 0.001, t = 2.7) but not in the high-constraint condition (b = 0.001, SE = 0.001, t = 1.8). In the low constraint condition with short previews (<=222ms, 156 observations),

reading times on the target character were significantly longer in unrelated preview condition than in semantically related preview condition *(b* = 0.229, *SE* = 0.071, *t* = 3.3). However, such effect was not significant with long previews (>222ms, 151 observations, *b* = 0.045, *SE* = 0.075, *t* = 0.6).

----------Figure 4 about here----------

When pre-target character was skipped, we did not observe any significant SPE (FFD: *b* = 0.0158, *SE* = 0.0173, *t* = 0.9; GD: *b* = 0.0229, *SE* = 0.0179, *t* = 1.3).

Identical preview effect. Identical preview led to shorter FFDs and GDs than unrelated preview (FFD: *b* = 0.121, *SE* = 0.036, *t* = 3.4; GD: *b* = 0.185, *SE* = 0.037, *t* = 4.9), but this preview benefit depended neither on the contextual constraint (FFD: *b* = 0.006, *SE* = 0.034, *t*= 0.2; GD: *b* = 0.051, *SE* = 0.042, *t* = 1.2) nor on the preview duration (FFD: *b* = 0.001, *SE* = 0.001, *t* = 0.9; GD: *b* = 0.001, *SE* = 0.001, *t* = 0.4).

When pre-target character was skipped, we still observed a significant identical preview effect (FFD: b = 0.0381, SE = 0.0178, t = 2.1; GD: b = 0.0425, SE = 0.0193, t = 2.2).

We did not find significant identical preview effect or semantic preview effect on skipping rates.

Post-target Character

On the post-target character, we observed a main effect of contextual constraint (FFD: b = 0.0629, SE = 0.0122, t = 5.1; GD: b = 0.0700, SE = 0.017, t =5.1). Reading times on the post-target character were longer in low constraint condition than in high constraint condition.

----------Table 3 about here----------

When the target word was not skipped, we did not find any significant preview effect. When the target character was skipped, we found a significant identical preview effect (FFD: b = 0.114, SE = 0.016, t = 7.2; GD: b = 0.133, SE = 0.017, t =7.9). Reading times on the post-target character were significantly longer in unrelated preview condition than in identical preview condition. We did not find a significant SPE or its interaction with prior fixation duration or with constraint.

Other Eye-movement Measures

Effects in other eye movement measures were in the expected direction as documented in Tables 1, 2, and 3. Further details relating to LMMs carried out for these measures are reported in the R scripts published at the website (http://read.psych.uni-potsdam.de/pmr2/).

Discussion

The present study investigated whether the preview-time-dependent SPE is modulated by contextual constraint in reading Chinese sentences. SPE was observed to be modulated by both contextual constraint (Schotter et al., 2015) and preview time (Yan et al., 2012). The crucial finding was a three-way interaction of preview condition, contextual constraint, and preview duration, suggesting both preview time and contextual constraint influence the SPE during word processing in sentence reading. For target words in low-constraint sentences, the semantic preview benefit was large for short preview duration and vanished with increasing preview duration. Yan et al. (2012) had reported the low-constraint result only as part of a post-hoc reanalysis of previously published data. Thus, our experiment provides the first test and independent conceptual replication of this speculation. For target words in the

high-constraint sentences, however, we found neither a main SPE nor an interaction between SPE and preview duration. In the following sections, the preview-time dependent SPE and the effect of contextual constraint are discussed in turn.

Preview-Time-Dependent Semantic Preview Benefit

Our use of preview time as a moderator for SPE demonstrates several effects related to different processing stages. The preview-time-dependent SPE indicates that word recognition is not always facilitated by the semantically related previews. Early processing of semantically related preview words, like accessing to the meaning of the preview words, benefits the processing of the target words. Information of semantically related previews, processed beyond a specific duration may lead to inappropriate semantic integration and actually interfere with processing of target words once the latter replace the preview words.

The results in our study are in agreement with Yan et al. (2012). Different from our study, Yan et al. (2012)did not manipulate contextual constraint but used only low-constraint sentences. Also, previews were semantically related or unrelated to the first character of two-character target words rather than to single-character target words as in our study. Importantly, despite these differences, both Yan et al. (2012) and our study showed the preview-time-dependent SPE in the low-constraint sentences. Recently, the preview-time-dependent SPE was also found during oral language comprehension (Pan et al., 2016). Together these studies indicate the importance and the necessity to explore the timelines of preview on the sematic preview effect. Previous studies have shown difference in reading skill and materials could also change the preview time and lead to a preview effect (Schotter, Reichle, & Rayner, 2014; Schotter & Leinenger, 2016; Veldre & Andrews; 2016).

It should be noted that our study using liner mixed models removed such effects. Future studies might investigate modulation of the preview-time-dependent SPE by difference in individuals and materials, which will be valuable in developing our understanding of parafoveal processing and computational models of eye movement control in reading.

The finding of preview-time-dependent SPE underlines the important role of preview time in the study of parafoveal processing. Traditionally, the relationship of a specific type of information between preview and target is manipulated, and the difference in fixation durations on the target is interpreted as evidence for parafoveal extraction of the critical information. Obviously, this interpretation assumes that variables not under experimental control (such as preview time) do not interact with the SPE. However, this was exactly the case in our experiment: Fixation durations on the target words changed with preview time in the semantically related preview condition, but not in the unrelated preview condition. Thus, our result of preview-time-dependent SPE represents an important extension to the boundary paradigm. Taking such interactions between covariates that are not under experimental control and experimental manipulations may be critical for progress in our understanding of parafoveal processing during reading.

However we did not find a modulation of the identical preview effect by preview time in the current study. Possibly this was due to the fact that contextual constraint (even in the low-constraint condition) in our study was much higher than in previous studies. The contextual constraint may accelerate the preview process and lead to a stable identical preview within a short preview time.

Influence of Contextual Constraint on the Semantic Preview Effect

The influence of contextual constraint on the SPE reveals an early and deep effect of context on processing of words in reading. Why was the time-dependent SPE modulated by contextual constraint? One possible reason is that the highly constrained context accelerates the integration of semantically related previews and triggers interference normally seen only for long preview durations. Specifically, in the high constraint context, both preview and context are available very early during preview (i.e., with short preview durations). This information may be consistent or inconsistent with target word or context. Inconsistent context may cancel semantic preview benefit. In contrast, in the low-constraint context, consistent or inconsistent preview information was obtained separately during short or long preview times. Thus, without or with very little top-down context information, preview of semantic relatedness may facilitate comprehension with short preview time and interfere with comprehension for long preview times.

In the present study, the contextual constraint was defined as the degree to which the constraint narrows down the range of possible continuations, empirically defined as the cloze probability of the highest probability continuation, ranging from 0 to 1 (Rayner & Well, 1996). There are other ways to measure the contextual constraint, like in Schotter et al. (2015), contextual constraint was defined as the cloze probability of the probability continuations those sharing a general idea. The latter way captures the extent to which the sentence constrains the meaning that is shared by the target and synonym. However, we used single-character words as the target words in the present study and they rarely have synonyms. Therefore, we manipulated contextual constraint in the traditional way.

The results of our experiment reveal the important role of context for parafoveal processing in reading. In principle, a wealth of contextual information may facilitate parafoveal words processing. Moreover, how well parafoveal words match context also influences the reading process. Given that words prior to and following the target words were kept constant across constraint conditions in the current study, the differences in SPE between high- and low-constraint sentences could only be due to the difference of contextual constraint. Thus, context not only influences parafoveal processing of low-level visual or orthographic information, but also parafoveal processing of high-level semantic information.

The absence of a SPE in the high-constraint condition in our study seems contrary to the findings in Schotter et al. (2015) where strong expectations from context were necessary for readers to obtain a SPE. The different results may be due to an advantage in semantic parafoveal processing for Chinese readers. Readers of the logographic Chinese script are always considered to process semantic information in the parafovea to a larger extent than readers of alphabetic script (Yan et al., 2009; Yan, Risse, et al., 2012). In agreement with this hypothesis, different from Chinese, in a study using German, greater semantic preview benefit was observed with long preview time (Hohenstein & Kliegl, 2014). Semantic information appears to be processed earlier for Chinese readers than by readers of alphabetic script. If that is the case, it is reasonable to conclude that the high-constraint context leads to a semantic preview benefit from a semantically related preview in alphabetic languages but to an interference effect in Chinese. Future studies are needed to examine the relationship between SPE and contextual constraint in different language systems.

Conclusions

The present results replicated the time-dependency of the SPE in Chinese and extended research on this effect by demonstrating a modulation by contextual constraint. Our results underline the importance of contextual effects in parafoveal processing, and highlight that word processing in sentences is a dynamic process of integrating semantic information in both a bottom-up way via preview and in a top-down way via context.

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Table 1. Pre-target character: Means (standard deviations)/number of observations of First Fixation Duration (FFD), Gaze Duration (GD), Single Fixation Duration (SFD), Fixation Rate (FR) in each condition (HC: High Constraint; LC: Low Constraint; Identical: Identical Preview; Related: Semantically Related Preview; Unrelated: Semantically Unrelated Preview)

	Identical	Related	Unrelated
FFD - HC	221(63)/340	220(68)/322	226(64)/319
FFD - LC	231(73)/336	224(58)/311	228(67)/339
GD - HC	222(66)/340	221(70)/322	229(67)/319
GD - LC	235(78)/336	228(66)/311	231(74)/339
SFD - HC	220(64)/337	220(67)/320	227(64)/315
SFD - LC	231(73)/329	223(58)/304	227(66)/335
FR - HC	0.43(0.5)/790	0.41(0.49)/787	0.4(0.49)/796
FR - LC	0.43(0.5)/782	0.4(0.49)/781	0.43(0.5)/781

Table 2. Target character: Means (standard deviations) /number of observations of First Fixation Duration (FFD), Gaze Duration (GD), Single Fixation Duration (SFD), Fixation Rate (FR) in each condition (HC: High Constraint; LC: Low Constraint; Identical: Identical Preview; Related: Semantically Related Preview; Unrelated: Semantically Unrelated Preview)

	Identical	Related	Unrelated
FFD - HC	248(72)/358	262(79)/372	269(83)/392
FFD - LC	264(85)/402	274(95)/388	279(94)/381
GD - HC	255(81)/358	272(87)/372	283(97)/392
GD - LC	276(94)/402	285(102)/388	294(105)/381
SFD - HC	249(73)/346	264(80)/352	271(84)/367
SFD - LC	266(86)/378	277(95)/369	281(94)/353
FR - HC	0.45(0.5)/790	0.47(0.5)/787	0.49(0.5)/796
FR - LC	0.51(0.5)/782	0.5(0.5)/781	0.49(0.5)/781

Table 3. Post-target character: Means (standard deviations) /number of observations of First Fixation Duration (FFD), Gaze Duration (GD), Single Fixation Duration (SFD), Fixation Rate (FR) in each condition (HC: High Constraint; LC: Low Constraint; Identical: Identical Preview; Related: Semantically Related Preview; Unrelated: Semantically Unrelated Preview)

	Identical	Related	Unrelated
FFD - HC	232(64)/423	252(79)/456	252(88)/450
FFD - LC	252(84)/416	266(89)/464	271(92)/447
GD - HC	237(79)/423	261(90)/456	259(92)/450
GD - LC	256(89)/416	280(114)/464	285(106)/447
SFD - HC	231(64)/414	252(79)/436	254(89)/433
SFD - LC	252(84)/406	266(88)/439	272(94)/418
FR - HC	0.54(0.5)/790	0.58(0.49)/787	0.57(0.5)/796
FR - LC	0.53(0.5)/782	0.59(0.49)/781	0.57(0.5)/781

Figure 1. Example sentence of high constraint and low constraint with three types of preview

High constraint-identical/related/unrelated

院子*里*打鸣*的*那只*鸡/蛋/府*还在*叫个不停*。

(Courtyard* in* crowing* of* that* rooster /egg/ palace * is still* boasting.)

That crowing rooster/egg/ palace is still boasting in the courtyard.

Low constraint -identical/related/unrelated

刘老汉*逮住*的*那只*鸡/蛋/府*还在*叫个不停*。

(Uncle Liu* caught* of* that* rooster /egg/ palace* is still* crowing.)

That rooster/egg/ palace caught by uncle Liu is still crowing.

Figure 2. Linear regression of first-fixation duration on target character of high constraint condition (Left) and of low constraint condition (Right) on single-fixation duration on pre-target character for unrelated (blue), semantically related (green), identical (red) preview conditions. This plot is based on logarithmic scales for both axes, and between-subject and between-item differences as estimated in the LMM were removed prior to regressions (i.e., this is a partial-effect plot).

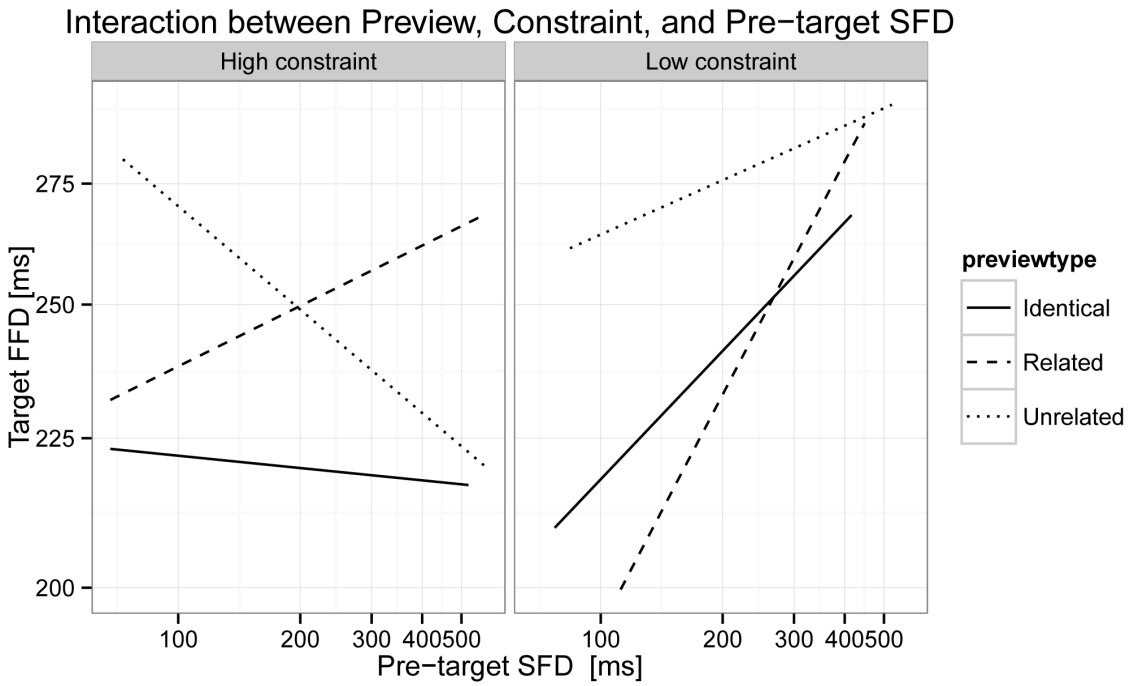

Figure 3. Preview effects from Yan et al., (2012). Linear regression of first-fixation duration (panel A), and gaze duration (Panel B) on target word on single-fixation duration on pre-target word for unrelated (bold-solid), semantic (bold-dashed), identical (bold-dotted), orthographic (simple dashed), phonological (simple dot-dashed) preview conditions using logarithmic scales for both axes. The vertical line indicates the mean log single-fixation duration on pre-target word. Between-subject and between-item differences for dependent variable and covariance in the LMM were removed prior to regressions.

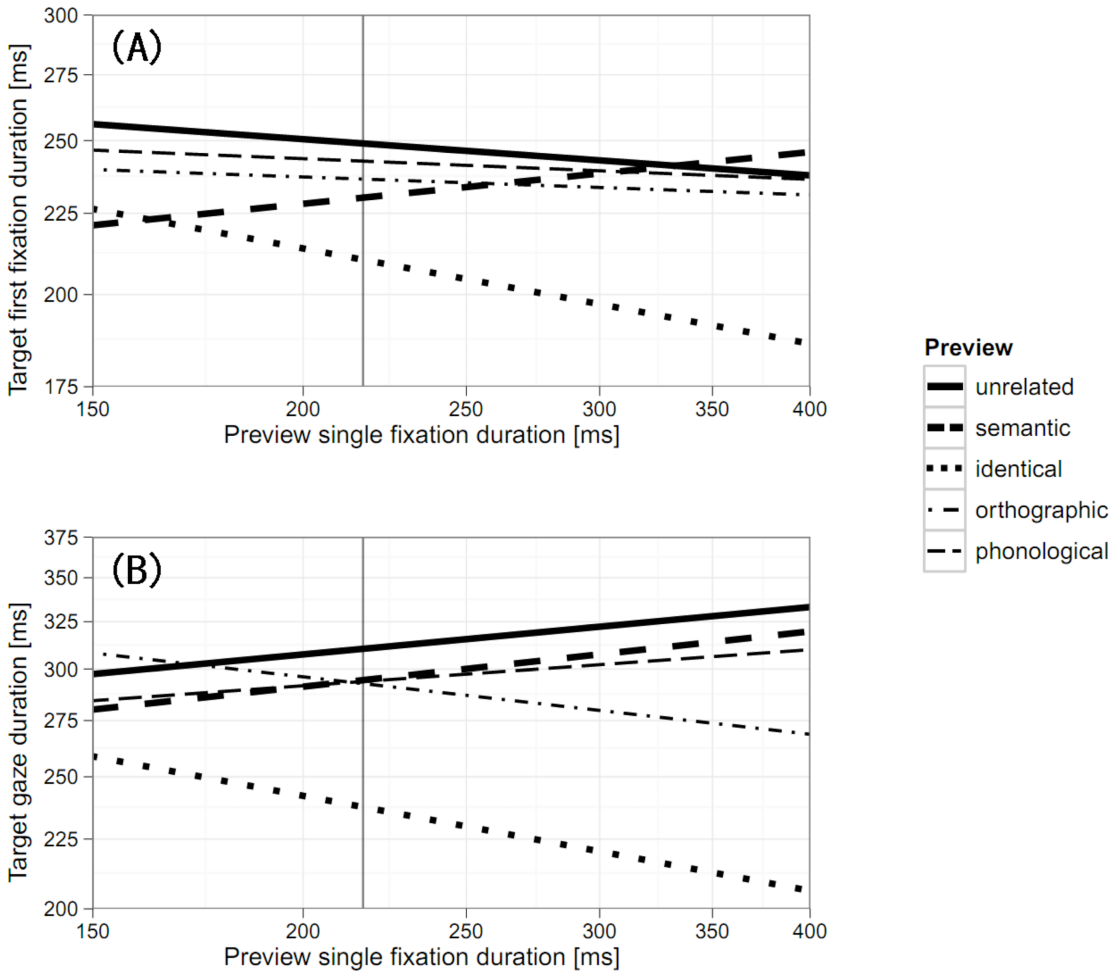

Figure 4. Linear regression of gaze duration on target character of high constraint condition (Left) and of low constraint condition (Right) on single-fixation duration on pre-target character for unrelated (blue), semantically related (green), identical (red) preview conditions. This plot is based on logarithmic scales for both axes, and between-subject and between-item differences as estimated in the LMM were removed prior to regressions (i.e., this is a partial-effect plot).