Orthographic Neighborhood Effects in Chinese Reading: A Self-Paced Reading Experiment

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Abstract: Orthographic neighbors are adjacent words or characters that are similar in sound or written form or both. This research explores whether orthographic neighbors have impacts on character recognition in Chinese reading. In a non-accumulative Self-Paced Reading (SPR) experiment, 52 native Chinese speakers were each presented with 130 Chinese sentences. Three types of prime characters were used: characters that are phonologically and orthographically similar, characters that are only orthographically similar, and irrelevant characters. Each participant's reaction time (RT) was collected. Experimental results revealed that: (1) When prime characters were phonologically and orthographically similar to target characters, there was no significant difference in participants' RT based on their responses to Ns, N-1s, N+1s, N+2s; (2) When prime characters were only orthographically similar to target characters, there was still no significant change in the readers' performance. The study implies that SPR may not be sensitive enough for detecting the effects of orthographic neighbors in Chinese reading.

1. Introduction

The writing systems of human languages, also referred to as scripts or orthography, vary according to their design principles. For instance, Chinese and English have dissimilar orthographic structures. In English, an orthographic neighbor is generally a word that differs from the target word by only one letter and has the same word length, remaining letters, and letter position, like "crash" and "crush" (Coltheart et al, 1977). In Chinese, orthographic neighbors are generally defined at the stroke or radical level. At the stroke level, an orthographic neighbor is a character that adds, removes, or replaces one or two strokes from the target character. (J. Wang, et al., 2014), such as "日 (rì) and "目 (mù)". While at the radical level, orthographic neighbors are characters that differ only in radicals, have the same structure, and contain the same left parts (Wang et al., 2015), such as "腌 (yān)" and "淹 (yān)".

We used a non-accumulative Self-Paced Reading research paradigm to investigate the effects of orthographic neighbors on target character recognition at the radical level and the role of character sound in the effects of orthographic neighbors in Chinese sentence reading. This research was guided by the following questions: (1) Do orthographic neighbor characters affect target characters' recognition at the radical level? If yes, how? (2) Is there a significant difference in the orthographic neighborhood effects at the radical level either in similar or different conditions of sound?

2. Literature Review

2.1 Theoretical Accounts of Orthographic Neighborhood Effects

Mcclelland and Rumelhart (1981) hypothesized that visual word recognition is a two-way process of obligatory satisfaction. When a word is presented visually, it can activate not only its

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own representation but also that of words that are similar to it either in meaning or in form (e.g., orthographic neighbors). This theoretical model provides a basis for studying the effect of orthographic neighbors. Tenpenny (1995) advanced the episodic theory of repetition priming and word identification, arguing that memories associated with the orthographic neighbors' processing may be activated in the recognition of a target word, leading to interference with them. Based on this theory, whether the target character can evoke episodic memories at the time of the prime character's processing under the non-accumulative SPR condition is questionable.

2.2 Orthographic Neighborhood Effects in Isolated Words and Sentences

When conducting studies on the effects of orthographic neighbors in isolated words, where words are presented one by one in a trial, most researchers have adopted a masked or unmasked priming paradigm (e.g., Perry et al., 2008), using orthographic neighbors and irrelevant words as prime words. Some studies (e.g. J. Wang, et al., 2014) showed that, during the recognition of isolated words, orthographic neighbors can inhibit the recognition of target words. However, Jiang and Wu (2022) revealed that not all orthographic neighbors in Chinese characters inhibited the processing of target characters. They tested the masked orthographic priming effect in L1 and L2, effect did not show in English native speakers, it occurred in Chinese speakers.

Frisson et al. (2014) claimed that prime words that are phonological overlap alone or only orthographic overlap did not have an effect under sentence reading, and the inhibition effect was only found when prime words are phonological and orthographic overlap.

2.3 Orthographic Neighborhood Effects in Phonology

In English sentence reading, phonological proximity affects lexical processing, slowing down sentence reading and decreasing correct sentence comprehension when the prime words and the target words have similar word sounds relative to non-phonological initiation under the SPR experiment (Acheson & Macdonald, 2011). In eye movement studies of Chinese, phonological overlap interfered with sentence reading, and participants read slower when reading tongue-twisting sentences, compared to reading normal sentences (Yan, Song, Liu, & Meng, 2017).

In summary, different types of research on the effect of orthographic neighbors have found that word sound and word form are influential factors that may inhibit or facilitate the recognition of target words in both typical and atypical reading conditions. However, few studies have examined this effect in Chinese by using SPR which can prevent readers from seeing the target word/character and its orthographic neighbors at the same time. With such a paradigm, if the priming effects of orthographic neighbors were strong enough, it could still be detected without readers' peripheral vision. In view of this literature gap, the study explores whether there are effects of orthographic neighbors at the radical level of Chinese characters with the Self-Paced Reading paradigm.

3. Methodology

3.1 Participants

A total of 52 healthy college students were recruited, divided into two teams, Team A and Team B. Team A (Group 1 and Group 2) included 30 participants, aged from 18 to 25 years (M=19.43, SD=1.55). Group 1 included 10 males and 5 females (M=19.67, SD=1.91), and Group 2 included 9 males and 6 females (M=19.2, SD=1.08). Team B (Group 3 and Group 4) was made up of 22 participants, aged from 18 to 26 years (M=21.09, SD=1.88). Group 3 included 5 males and 6 females (M=21.27, SD=2.24), and Group 4 included 6 males and 5 females (M=20.09, SD=1.64).

There was no apparent discrepancy in age and sex ratios between the two groups in each team. As native Chinese speakers of Mandarin, all participants were right-handed, had the normal naked-eye vision or corrected vision, and had no color blindness or color weakness.

3.2 Materials

In this research, there were 65 pairs of experimental materials, each pair had 4 sentences, making a total of 260 complete and semantically coherent sentences. Each sentence contained a prime

character and a target character, with the prime character preceding the target character and separated by 2 characters (see Table 1).

Table 1 Example prime sentences

	Target character	Prime character	Form	Sound	Prime type	Sentences
Set 1	枸 (gǒu)	拘 (jū)	Similar	Different	FR	1.他仍然能在被**拘**时喝**枸**杞茶 这是何的待遇 (Experimental)
		扣 (kòu)	Different	Different	IFR	2.他仍然能在被**扣**时喝**枸**杞茶 这是何等的待遇啊 (Control)
Set 2	枸 (gǒu)	狗 (gǒu)	Similar	Similar	SR	3.那只**狗**站在**枸**杞树旁等待着 主人的出现 (Experimental)
		猫(māo)	Different	Different	ISR	4.那只**猫**站在**枸**杞树旁等待着 主人的现 (Control)

In Set 1, the prime characters fell into two types. The first type was only orthographically similar to the target characters (form-related characters) in the experimental sentences. For example, "拘 (jū)" is a form-related prime character (FR hereafter) intended to prime "枸 (gǒu)". The others in the control sentences were orthographically dissimilar to the target characters. In this study, they were called irrelevant characters (IFR henceforth). That means "扣 (kòu)" is an IFR of "枸 (gǒu)".

In Set 2, primes in experimental sentences were phonologically and orthographically similar to the target characters (sound-related character, SR). For instance, "狗 (gǒu)" is an SR intended to prime "枸 (gǒu)". Primes in the control sentences were phonologically and orthographically dissimilar to the target characters. They were irrelevant characters compared to the sound-related characters (hereafter ISR). For example, the ISR "猫 (māo)" was related to the SR "狗 (gǒu)". FR and IFR, SR and ISR were semantically related. The example materials were shown in Table 1.

In this research, the orthographic neighbor was defined as a prime character with the same structure (i.e. the left and right structure) as the target character. Between the prime and target, only the left radical was different, such as"跑 (pǎo)" and "鲍 (bào)".Furthermore, the similarity of characters' sounds meant that the vowels and rhymes were the same, but the tones could be different, such as "烘 (hōng)" and "哄 (hǒng)".

At the same time, 44 were set up with questions to ensure that the participants understood the meaning of the sentences correctly. For example, the original sentence read: "那只**狗**站在**枸**杞树旁等待着主人的出现 (The dog is standing by the wolfberry tree, waiting for its owner to appear)". The question was "那只**狗**是站在**苹果**树旁吗？ (Is that dog standing by the apple tree?)".

3.3 Procedure

Participants in Team A each read 130 randomly presented sentences. Group 1 read experimental sentences from Set 1 (e.g., sentence 1), and control sentences from Set 2 (e.g., sentence4). Group 2 read experimental sentences from Set 2 (e.g., sentence 3) and control sentences from Set 1 (e.g., sentence 2). Participants in Team B read 130 sentences randomly, in which all four types of sentences were included. However, they would not read the two sentences in the same set.

All the participants had to do the practice experiment. Before each sentence, there was a "+", participants should press the space key. They needed to press "F" to complete the reading from one character to the next, based on their reading speed. Most of the characters were in white, but for the sake of preventing participants from being distracted by the simple repetition of keystrokes, some characters were set in red that required participants to press the "J". Participants were required to press "Z (for right)" or "M (for wrong)" to answer the judgment questions.

If they understood how the experiment was conducted, they would be given a formal experiment according to their group, with Group 1 and Group 3 doing List 1 and Group 2 and Group 4 doing List 2.

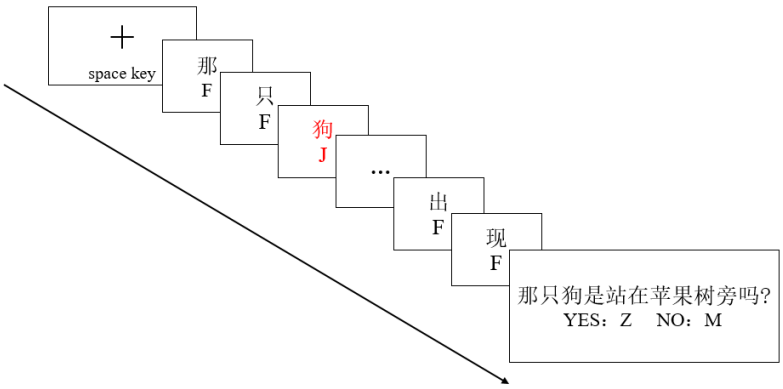

Figure 1. Experimental trial procedure

3.4 Data collection

Throughout the experiment, data on participants' response times and responses to questions would be recorded. The response times of participants would be analyzed for the prime character P, the target character N, the character before the target character N-1, and the two characters after the target character N+1, N+2. The correct responses of participants to the questions would be counted to examine whether they had read the material carefully and comprehended the sentence meaning.

4. Results

4.1 Results of Experiment 1

We firstly counted the percentage of correct answers to the questions, and the results demonstrated that each subject answered the questions with a correct rate of more than 88%, which means that the subjects read and understood the sentences carefully. Therefore, the data collected from all the 52 participants were valid. We calculated the average reaction time (hereafter RT) for all the key characters. The average RT of Team A is shown in Table 2.

Table 2 Average RT (Unit s) of Team A

	Set 1		Set 2		Total
	FR	IFR	SR	ISR	
N	0.285017236	0.337364228	0.345286717	0.282480409	0.313526321
N+1	0.276982963	0.348259231	0.348582593	0.292551835	0.317713277
N+2	0.283982397	0.360676608	0.375074284	0.311302421	0.334007829
N-1	0.277345665	0.34121953	0.325780058	0.276005563	0.306065568
P	0.286744588	0.35985482	0.330503713	0.282822272	0.316017202
Total	0.282014570	0.349474883	0.345045473	0.289032500	0.317466039

As shown in Table 2, in Set 1, the average RT in the FR case remained in the interval [0.2773,0.2867] with a difference close to 0.0094s. In the IFR case, the situation still had little change, the difference was merely 0.0233s. In Set 2, when SR and ISR were prime characters, the participants' RTs for P, N, N-1, N+1, N+2 were close, with the largest range of only 0.0493s ([0.3751,0.3258]). Thus, we reported that FR and SR had no notable effect on the recognition of target characters when they were used as the prime characters.

We did T-tests to determine if there were effects in a statistically significant way by analyzing the p-value. We made the following hypotheses about the FRs and IFRs, SRs and ISRs：

$H0_1$: It is assumed that participants' RT for P, N-1, N, N+1, and N+2 in the FR condition was not significantly different from those in the IFR condition.

$H1_1$: It was assumed that participants' RT for P, N-1, N, N+1, and N+2 in the FR condition was significantly different from those in the IFR condition.

$H0_2$: It was assumed that participants' RT for P, N-1, N, N+1, and N+2 in the SR condition was not significantly different from those in the ISR condition.

$H1_2$: It was assumed that participants' RT for P, N-1, N, N+1, and N+2 in the SR condition was significantly different from those in the ISR condition.

Table 3 P-values of Set 1 and Set 2

	P	N-1	N	N+1	N+2
FR&IFR	0.074	0.0497	0.117	0.0615	0.0687
SR&ISR	0.192	0.129	0.124	0.116	0.0702

In the analysis of FR prime characters, we can find a special value. The p-value was less than 0.05 at N-1, which means that in sentences the P affected the reading of N-1. However, from the other four data analyses, this effect was not present, especially for N (p-value 0.117). The possible reason was the presence of reading speed errors among the participants. Overall, however, we did not reject the null hypothesis $H0_1$ at a significance level of 5%. All p-values were greater than 0.05 ins Set 2. When the significance level was 5%, we did not reject the null hypothesis $H0_2$.

That was, the orthographic neighborhood effect was not significant in this paradigm.

4.2 Results of Experiment 2

The results of Experiment 2 were similar to those of Experiment 1, as shown in Table 4. In Experiment 2, the average RTs of participants revealed that the RT difference for five key characters was still negligible under the same set of prime characters. The changes in participants' RT on the target characters after seeing the prime characters were short sufficiently.

Table 4 Average RT (Unit s) of Team B

	Set 1		Set 2		Total
	FR	IFR	SR	ISR	
N	0.346277439	0.307198894	0.291578896	0.291358287	0.309154639
N+1	0.311501333	0.31856997	0.299451328	0.311379546	0.310198285
N+2	0.329494479	0.313346739	0.306911582	0.324388612	0.318556550
N-1	0.316406703	0.296040035	0.275293347	0.285122112	0.293231932
P	0.326940994	0.313376016	0.288026470	0.300573160	0.307230619
Total	0.326124190	0.30970633	0.292252320	0.302564340	0.307674410

Then, T-tests were performed on Experiment 2 to analyze the p-value. The same hypotheses as Experiment 1 were made, and the regression analysis results were as follows.

Table 5 P-values of Set 1 and Set 2

	P	N-1	N	N+1	N+2
FR&IFR	0.3294	0.175	0.8048	0.3291	0.1901
SR&ISR	0.386	0.3648	0.6534	0.6314	0.3032

According to the results of the p-values, in any case, they were greater than 0.05, so we cannot reject the null hypothesis when the significance level was 5%. Despite the adjustment of experimental materials, the results of Experiment 2 were the same as those of Experiment 1. There was no significant effect on the participants' reading performance in the SPR condition. This finding deviated from most of the previous studies.

5. Discussion and Conclusion

From the results of both experiments, we observed no evidence for the orthographic neighborhood effects of either form-related prime characters (FR) or sound-related prime characters (SR). Our findings are in contrast with those of Zhu (2022). In her eye movement experiments, FRs at the radical level showed facilitation effects; SRs engendered inhibition effects, demonstrating

that character sounds may play a crucial role in the orthographic neighborhood effects. However, in this research, no significant orthographic neighborhood effect was identified.

Arguably, orthographic effects at the radical level in Chinese reading do exist but they are not prominent as expected. There are two possible reasons. In our experiment, we used the paradigm of SPR. This method was less sensitive in detecting orthographic effects than Zhu's (ibid.) eye-movement technique. Furthermore, we used a smaller sample of participants than in Zhu's experiment. These factors might account for the disparity in results between the two studies. The following two conclusions could be drawn: (1) At the level of the radicals of Chinese characters, orthographic neighbors had no significant effect on the target character recognition in Chinese reading; (2) The character sound had no significant effect on orthographic neighbors' recognition.

There are three theoretical implications. First, methodologically, the present study shows that the paradigm of non-accumulative SPR is not sensitive enough to detect any orthographic neighborhood effect. Second, the research demonstrates that the orthographic neighborhood effects may not be adequately strong. The effects are likely to be subtle, and their intensity and outcomes may vary depending on factors including reading conditions. Last, in this study, Chinese as an under-explored language was examined, which may provide insights into orthographic neighborhood effects from the perspective of the Sino-Tibetan language family. Future studies could compare Chinese and other languages in orthographic neighborhood effects.

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