Chinese Orthographic Priming in Lexical Decision and Naming

Jei-Tun Wu Hsin-Chin Chen

National Taiwan University

Running heads: RELATIVE FREQUENCY ON ORTHOGRAPHIC PRIMING

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Abstract

Accompanied with the reliable facilitation effect of semantic (instead of homophonic) priming on character recognition and naming found in previous research, it was also observed that priming with orthographically similar characters inhibits recognition and naming of targets. The first two experiments manipulated prime character frequency, orthographic similarity, and SOA (stimulus onset asynchrony) in lexical decision and naming tasks. In the lexical decision task, the target characters which were preceded by an unmasked, orthographically similar prime of higher frequency were responded to slower than their dissimilar pair controls with SOAs of 50 ms and 500 ms. A similar inhibition effect was also observed in the naming task. When the SOA duration was extended to 1000 ms in Experiment 2, a significant inhibition effect was observed not only under conditions with primes of higher frequency but also with primes of lower frequency. In Experiment 3, pseudo-character primes were included. It was found that pseudo-character primes obtained no effect upon target recognition while manifesting a small inhibition effect on target naming under the prime exposure duration of 500 ms. In Experiment 4, an additional prime condition of free radicals in isolation was included. It was found in Experiment 4 that with the SOA of 50 ms or 500 ms, the embedded right component radical in isolation facilitated the recognition of the target character embedding it, while not exerting any effect on character naming.

Keywords: lexical access, character recognition, character naming,
frequency effect, character frequency, prelexical phonology,
neighborhood frequency effect, orthographic prime inhibition.

By conducting a series of studies using the lexical decision task with the priming paradigm, Grainger and colleagues (Ferrand & Grainger, 1992; 1993; 1994; Grainger & Ferrand, 1994; Segui & Grainger, 1990) attempted to find the time course of activating orthographic and phonological information. With very short exposure durations of masked non-word primes, the SOA (stimulus onset asynchrony) from 17 ms to 50 ms, the orthographic facilitation effect was observed. The effect size observed was the largest at about 30 ms and then disappeared at 64 ms. In the meantime, the homophonic facilitation effect also started to appear when the prime exposure duration was 32 ms and increased along with the SOA (Ferrand & Grainger, 1992; 1993; 1994). While the prime was a word and the exposure duration longer than 64 ms, the orthographic similarity effect turned out to be inhibitory instead, although the homophonic effect was still facilitatory. The facilitatory homophonic effect changed to be inhibitory only when half of non-word foil targets were pseudo-homophones (Grainger & Ferrand, 1994). These results when combined with that from a previous study (Segui & Grainger, 1990), depicts a picture showing the time course of an alphabetic (French) lexical activation. In Segui and Grainger (1990), only prime words with frequency higher than targets obtained the orthographic inhibition effect at the short SOA of 60 ms, while at the long SOA of 350 ms only lower frequency words obtained the orthographic inhibition effect.

A modified version of the interactive activation model initially developed by McClelland and Rumelhart (1981) was then proposed by Ferrand and Grainger (1992) as follows. The model is characterized by a triangular structure, including a layer of sub-lexical orthographic units, a layer of sub-lexical phonological units, and a level of lexical representations (word level). On presentation of a written word, the visual input activates a set of orthographic units, which, in turn, send activation on to the word level and phonological units with which it is directly linked. The build-up of activation at the lexical and phonological levels thus lags behind the build-up of activation at the orthographic level. This explained that at very short prime exposure of 32 ms only orthographic units will be sufficiently activated to facilitate subsequent target recognition. With longer prime exposures (e.g. 64 ms) both phonological and word units will be more activated to influence subsequent target recognition. Activated word units will inhibit target word recognition via within-level inhibition, whereas activated phonological units will provide facilitatory inputs to the target representation and hence facilitate recognition. Thus, at prime exposures of around 60 ms, facilitation effects of phonological prime-target overlap are present; but the facilitation effects of orthographic overlap are cancelled by lexical inhibition.

According to this conception of the visual word recognition process, orthographic information is fed directly into the mental lexicon without any prior transformation into a phonological code. This is in conflict with the viewpoint of phonological mediation by some investigators (Lukatela & Turvey, 1991; Van Orden, Pennington, & Stone, 1990) who have proposed that there is no direct link between orthographic units and word units (also see Ferrand & Grainger, 1994).

Let's go back to the issue of orthographic inhibition effects. When the SOA was also manipulated orthogonally with neighborhood frequency, Segui and Grainger (1990) obtained different effects of neighborhood frequency on lexical decisions under different SOA's. When masked prime words were presented for 60 ms, only the primes that were higher frequency orthographic neighbors of the target interfered with target processing, relative to an orthographically dissimilar prime control condition. On the other hand, when the SOA was extended to 350 ms for unmasked primes, interference was observed only with lower frequency prime words, while those with higher frequency prime words no longer produced any interference or facilitation. The results were interpreted in terms of activation and selection processes. For short prime presentations, it was assumed that only the unconscious process was performed; thus high frequency primes would obtain a high enough level of activation to inhibit the processing of its orthographic neighbor target. For prime presentations long enough to perform conscious processing, a selection process to account for the result was proposed as follows. If the prime is low frequency and the target a higher frequency neighbor of this word, then the target representation must be inhibited for the prime to be identified. If the target is then presented for identification, it would take longer if the inhibition has not had time to dissipate. On the other hand, using their account, if the prime was high frequency and the target a lower frequency one, then on prime-word identification the target representation would not be a strong competitor in selection processes and would not require inhibition. This was rather a sophisticated account and it was still not easy to convince others why a higher frequency neighbor prime had lost its inhibitory effect when the SOA was extended longer. In a review article, Andrews (1997) stated that neighbors have consistently been reported in studies on English to facilitate target naming and lexical decisions (e.g. Forster & Shen, 1996; Johnson & Pugh, 1994; Sears, Hini, & Lupker, 1995), and thus treated Grainger's French inhibitory effect of neighbors as arising from sophisticated guessing strategies in perceptual identification tasks or lexical decision strategies adopted in unusual stimulus environments.

Orthographic inhibition effects were also obtained in some studies on Chinese character identification with priming paradigms (e.g., Chen & Shu, 2001; Perfetti & Tan, 1998; Wu & Chen, 2000; Wu & Chou, 2000). Perfetti and Tan (1998) manipulated SOA in their Chinese character naming tasks to compare the relative magnitudes of priming effects among orthographic, homophonic, and semantic primes. Evidence supporting their view of universal phonology was then provided. They found that homophonic primes showed greater facilitation effects than semantic primes on naming target characters. In addition, when the SOA was 43 ms, they obtained a graphic facilitation effect. However, when the SOA was 57 or 85 ms, they obtained a graphic inhibition effect. And when the SOA was extended longer, graphic primes exerted no significant effect on target naming. Wu and colleagues (Wu & Chen, 2000; Wu & Chou, 2000) and Chen and Shu (2001) tried to replicate the finding of Perfetti and Tan (1998), but failed to obtain the similar time course pattern. Nevertheless, graphic inhibition effects were oberved by all of them. We thus think that orthographic similarity would be a critical factor in the process of word recognition. It is without doubt that a prelexical analysis of orthography is of course necessary for the identification of a word and for the retrieval of its phonological and semantic properties. For correct identification, it is natural to avoid confusion or interference from other words. Inhibitory connections among similar forms of words are then inevitable when they are activated simultaneously. Is the picture of orthographic inhibition in the lexical identification for Chinese the same as, or different from, that of any alphabetic system? This yielded the motivation to complete the present study in which two of four experiments were initiated five years ago.

The present study adopted a research strategy similar to Segui and Grainger (1990). In studies using alphabetic orthographies, an orthographic neighbor refers to a word that can be created by changing a single letter of a target word. While in the present Chinese study an orthographic neighbor is defined as a character sharing a phonetic radical with the target character. For example, a target character, **他**, has many neighbor characters, **地**, **池**, and **馳**. All of these characters share the same phonetic radical, **也**. It is noted that in this kind of study the graphic similarity between a target and its neighbor is about half size of a character, while in alphabetic studies the difference between a target word and its neighbor is only a letter. Using the priming procedure in lexical decision and naming tasks, the SOA and neighbor character frequency relative to the target character were manipulated. According to the arguments from the above paragraphs, the orthographic inhibition effect is to be expected and moderated by neighbor character frequency and stimulus onset asynchrony, both on lexical decision and naming (Experiments 1 and 2). Due to differences between orthographies of French and Chinese, the detail pattern of inhibition might be somehow different from Segui and Grainger (1990). Further experiments (Experiments 3 and 4) will explore the possible priming effects when the primes are pseudo-characters or free component radicals. If pseudocharacter primes do not exert any orthographic inhibition, the phenomenon of orthographic inhibition could be classified into a linguistic domain rather than a perceptual domain. Because a pseudo-character possesses no lexical status, according to the notion of the interactive activation model there is no within-level competition to be expected between two lexical representations. If the component radical of a target character is presented in isolation as a prime to induce the sub-lexical process of radical, it is expected that the target character process would be benefited via a between-level facilitation.

Experiment 1

Orthography does not covary with phonology in Chinese. Because orthographically similar characters are usually pronounced differently, for correct identification readers have to keep away from confusion or interference from orthographically similar characters. Segui and Grainger (1990) obtained different effects of neighborhood frequency on lexical decision under different SOA's. When prime words were briefly presented for 60 ms, only the primes that are higher frequency orthographic neighbors of the target interfered with target processing. In contrast, when the SOA was extended to 350 ms, interference was observed only with lower frequency prime words. A possible alternative explanation to Segui and Grainger's account of higher frequency primes losing their effect under the long SOA can be as follows. Because their stimulus words were French, a shallow alphabetic orthography, the phonology covaries with the orthography. When the SOA is long enough, the phonology would be sufficiently activated for higher frequency prime words. This might produce a phonological priming facilitation effect on target processing to compensate the inhibition resulting from competition among orthographically similar neighbors. If this alternative explanation proves correct, then we would find an inhibition effect from primes with higher frequency as well as with lower frequency for longer SOA in experiments using Chinese characters as stimuli. We conducted the present experiment to test this hypothesis. Two levels of SOA, 50 ms and 500 ms, were used to cover a range wider than that of Segui and Grainger (1990).

Method

Participants. According to the manipulation of task (lexical decision, naming) and SOA (50, 500 ms) factors, one hundred participants were randomly assigned to four groups, each with 25 participants. They were recruited from the participant pool at National Taiwan University to participate in this experiment for partial fulfillment of course requirements. All were fluent readers of Mandarin with normal or corrected-to-normal vision.

Design and stimuli. Participants were randomly assigned to one of four groups representing combinations of two between-subjects factors of task (lexical decision vs. naming) and SOA (50 ms vs. 500 ms). Each group of participants received the same 2 ×2 within-subjects factorial consisting of two factors of prime frequency (higher vs. lower), and orthographic relatedness (similar vs. unrelated). This formed a 2 × 2 × 2 × 2 four-way factorial design.

Forty eight medium-frequency characters were selected as a target stimulus set from the character database of Wu and Liu (1987). The character frequency ranged from 77 to 150 per million (with an average of 112). For each target character, four prime characters representing different combinations of a 2 × 2 within-subjects factorial were coupled. Two of them were orthographically similar to the target characters while the other two were unrelated. Orthogonally, half of them were with character frequency higher than the target character, ranging above 250 per million, and the other half were with relatively lower frequency, ranging below 13 per million. The number of strokes was also equated among different conditions. The complete list of target characters and prime characters is presented in Appendix A along with the number of strokes and the character frequency. For the lexical decision task, equal numbers of pseudo-character foil targets were constructed by re-pairing two radicals which are correct usage in position in real characters. For each participant, each target character appeared just once and was preceded by only one of four different types of prime. The assignment of each target character into the different prime conditions was counter-balanced between participants. Forty eight filler trials with target characters not restricted to medium-frequency and with the primes unrelated to the targets were further constructed and mixed with those experimental trials. Both experimental and filler trials summed up to 96 trials in total for the naming task. With respect to the lexical decision task, additional 96 trials with pseudo-character targets and a different set of prime characters were constructed to sum up with 192 trials in total. A total of

20 additional characters were also selected for practice trials.

Apparatus and procedure. The experiment was controlled by an IBM PC/486 compatible microcomputer. Stimuli were presented in isolation on the center of a 17 inches VGA-adapted, 60Hz, display. A voice-activated circuit linked with a microphone was interfaced to the computer to detect the onset of the participant's pronunciation in the naming task. Reaction times (RTs) and the timing of stimulus display were both measured to the nearest millisecond and synchronized with the onset of video frame refreshing. The software used for controlling experimental procedures and data handling was adopted from Wu (1995). Participants received 20 practice trials each with feedback. Erroneous responses in the practice trials were repeated until a correct response was made. No feedback was given on subsequent experimental trials.

On each trial, the following sequence of events occurred: (a) an asterisk, used as a fixation point, was presented at the center of the monitor and lasted for 700 ms accompanied with a 100 Hz warning tone for 150 ms, and then disappeared to leave the screen blank for 100 ms; (b) the prime character occupying a 24 × 24 dot matrix area which subtended a visual arc of approximately 1.2 degrees, from the viewing distance of 60 cm, was then presented in isolation at the center of the screen for a period of time, depending on which SOA group the participant was assigned to; (c) the target character was then presented at the same location to replace the prime character and then remained there until the computer detected the participant's key stroke in the lexical decision task or the onset of the participant's pronunciation in the naming task, the RT timing started from the presentation of the target character until the response was made; (d) in the naming task, the phonetic symbols used in Taiwan to stand for the correct pronunciation were then presented above the stimulus character, and via a remote connection line, the experimenter seated behind the participant either pressed one of two buttons to indicate that a correct pronunciation of the character triggered the computer, or the other button to indicate that an incorrect pronunciation of the character or some other sound (such as a cough) triggered the computer; and (e) the whole screen was immediately erased and there was a 1-s blank before an asterisk accompanied with a warning tone for the next trial was presented.

All the 48 experimental trials, 48 filler trials, and additional 96 pseudo-character trials in lexical decision, were evenly and randomly divided into 12 blocks. Each block was composed of four trials from different prime conditions, one for each, and four fillers, and additional eight pseudo-character target trials for lexical decisions.

An on-line random assignment with a block randomization shuffling procedure was performed individually so that each participant received an idiosyncratic random sequence of block-arranged stimuli.

All participants were tested individually. Upon arrival each participant was seated in a sound-deadened room and received written instructions on the screen. Both accuracy and speed were emphasized. The participants were required to take a rest after a suitable number of trials. The entire experiment took approximately 20 minutes for each participant.

Results and Discussion

In calculating the mean RT of correct responses for each condition within each participant, those trials with RTs less than 200 ms (possible anticipation), or 2.5 standard deviations more than the mean of the condition to which the trials belonged, were treated as outliers. The percentage of outliers was 4.1%. The re-computed mean correct RTs and mean percentages of errors across participants under different conditions of prime frequency × orthographical relatedness for each group are shown in Table 1.

Insert Table 1 about here

Table 1 shows that in general it took slightly longer for naming than for lexical decision. Furthermore, it also took longer to respond to the targets preceded by orthographically similar prime with relatively higher frequency, as compared to other conditions. The statistical significance of these effects was assessed by analyses of variance (ANOVAs) across participants, F_1, and across stimulus items, F_2.

Mean RT obtained for all participants in Experiment 1 were submitted to two three-way ANOVAs with factors of SOA (50, 500 ms), prime frequency (relatively higher, lower), and orthographical relatedness (similar, control), performed separately on the data for lexical decision and naming.

The three-way ANOVA with factors of SOA, prime frequency, and orthographical relatedness, performed on lexical decision, showed a similar pattern as the above four-way ANOVA. The significant sources of variation were relatedness, $F_1(1, 48) = 41.14$, $MSe = 1212$, $p < .001$, $F_2 (1, 47) = 43.62$, $MSe = 3673$, $p <.001$, prime frequency, $F_1(1, 48) = 36.74$, $MSe = 1372$, $p < .001$, $F_2 (1, 47) = 9.45$, $MSe = 11210$, $p <.01$, and relatedness $\times$ prime frequency, $F_1(1, 48) = 17.59$, $MSe = 1933$, $p < .001$, $F_2 (1, 47) = 13.33$, $MSe = 5424$, $p <.001$. The effect of SOA was also significant across items, $F_1(1, 48) < 1$, $F_2 (1, 47) = 12.71$, $MSe = 3419$, $p < .001$. A further analysis showed that the simple main effect of relatedness was significant under the higher prime frequency condition, $F_1(1, 96) = 52.85$, $MSe = 1573$, $p < .001$, $F_2 (1, 94) = 49.22$, $MSe = 4549$, $p <.001$, while it was not significant under the lower prime frequency condition, $F_1(1, 96) < 1$, $F_2 (1, 94) = 1.18$. This supports the impression from Table 1 that a preceding orthographically similar prime with relatively higher frequency exerted an inhibitory effect on lexical decision to the target, while a prime with lower frequency exerted no effect.

A quite different pattern of results were obtained from the similar three-way ANOVA performed on the naming data. The main effect of relatedness was significant, $F_1(1, 48) = 30.62$, $MSe = 1247$, $p < .001$, $F_2 (1, 47) = 14.67$, $MSe = 5484$, $p <.001$. A significant main effect of SOA was found only across items, $F_1(1, 48) = 1.07$, $MSe = 15731$, $p > .05$, $F_2 (1, 47) = 15.40$, $MSe = 2616$, $p < .001$. It should be noted that the effects concerning the factor of prime frequency were not significant in the naming tasks, but different from those in lexical decisions. This implied that the differing effects of relatedness were both significant for higher prime frequency and for lower prime frequency.

To sum up, there were several points worth noticing. First, the response latencies for lexical decisions were slightly faster than those for naming. This confirms the general pattern from previous studies on Chinese character lexical decision and naming (e.g., Liu, Wu, & Chou, 1996; Wu, Chou, & Liu, 1994). Second, the prior presentations of orthographic neighbors with frequency higher than the targets always exerted inhibition on lexical decision to the targets, irrespective of whether the presentation of primes were brief or long. This is consistent with our prediction, stated before, while differing from Segui and Grainger (1990) in which the neighbor prime of higher frequency no longer exerted inhibition on target lexical decisions when the SOA was long. In the present experiment we did not find any significant inhibition effect in lexical decision from the neighbor prime of lower frequency for the prime presentation duration of 500 ms. Maybe it was still not long enough for activating the prime sufficiently to compete with the target. Third, whether the SOA was short or long, and whether the prime frequency was higher or lower relative to the target, the orthographic neighbors always produced inhibition on the naming response to the target. Maybe because most prime-target pairs were not homophonic, the inhibition obtained in the naming task which demands phonology was larger than in the lexical decision. It is worth noting that, according to Andrews (1997), all of the alphabetic studies using naming tasks had not found any inhibition effect except for naming low-density words in the Spanish study of Carreiras et al. (1997). Neighborhood-size or neighborhood-density is defined as the number of neighbors for a given word. A high-density word is a word with more neighbors. A low-density word is a word with a few neighbors. In this experiment, the orthographic inhibition effect not only was obtained, under higher frequency primes, for lexical decisions, but also was obtained, under higher and lower frequency primes, for naming. The orthographic inhibition effect seems to be more obvious for naming in Chinese.

Experiment 2

In Experiment 1, we obtained similar lexical decision task results as Segui and Grainger (1990) for short presentations of primes, while different results for long presentations of primes. According to the reason stated previously, for Chinese character recognition it should be found for neighbor primes, whether with high frequency or with low frequency, to produce inhibition on target process as long as the duration of prime presentation is sufficient. A SOA of 500 ms might not have been sufficient so that we did not find any significant inhibition effect from the neighbor primes of lower frequency. For convenience, in this experiment we extended the SOA to 1000 ms while other things did not change.

Method

Participants. Forty participants from the same pool as in Experiment 1 were recruited in this experiment. They were randomly assigned to two groups. One group of participants received the lexical decision task and the other group received the naming task. There were 20 participants in each group.

Design and stimuli. The same design and stimuli of Experiment 1 were adopted except that the SOA was fixed at 1000 ms. This reduced the design into a three way factorial with the factor of task being between-subject and the other two of prime frequency and orthographical relatedness being both within-subject.

Apparatus and procedure. The same apparatus and procedure used in Experiment 1 were adopted in this experiment.

Results and Discussion

The data analyses were similar as in Experiment 1. The mean correct RTs and mean percentages of errors across participants under different conditions for each Group are shown in Table 1. Mean RT data obtained for all participants in this experiment were submitted to two two-way ANOVAs with factors of prime frequency (relatively higher, lower), and orthographical relatedness (similar, control), performed separately on the data for lexical decision and naming.

The two-way ANOVA with factors of prime frequency, and orthographical relatedness, performed on lexical decision, showed a slightly different pattern as compared to Experiment 1. The main effect of relatedness was significant, $F_1(1, 19) = 14.78$, $MSe = 2494$, $p < .01$, $F_2\ (1, 47) = 17.47$, $MSe = 5637$, $p <.01$. The effect of prime frequency was marginally significant only across participants, $F_1(1, 19) = 4.61$, $MSe = 685$, $p < .05$, $F_2\ (1, 47) = 1.22$, $MSe = 4169$, $p > .05$. The interaction effect of relatedness × prime frequency was not significant, $F_1(1, 19) < 1$, $F_2\ (1, 47) < 1$. This indicated that a preceding orthographically similar prime exerted an inhibitory effect on the lexical decision of the target regardless of higher and lower prime frequency. Nevertheless, the prime with higher frequency seemed to produce more inhibition than that with lower frequency. These results were consistent with that of Experiment 1.

Moreover, the two-way ANOVA performed on naming showed a pattern consistent with that of Experiment 1. Only the main effect of relatedness was significant, $F_1(1, 19) = 7.44$, $MSe = 2053$, $p < .05$, $F_2\ (1, 47) = 4.78$, $MSe = 11217$, $p <.05$. All other effects were not significant.

When Experiment 2 extended the SOA to 1000 ms, the resultant pattern agreed with the tendency of Experiment 1. Both for lexical decision and for naming, we obtained a significant effect of inhibition on target recognition for neighbor primes with lower frequency. Because the inhibition effect from neighbor primes with higher frequency is still significant and no longer decreasing, compared to Grainger's result, it seems that orthographic inhibition in Chinese is more robust than that in French or other alphabetic systems.

Experiment 3

Experiments 1 and 2 showed that orthographically similar character primes with frequencies higher than target characters manifests strong inhibition effects in either lexical decision or naming. Unlike the results from an alphabetic orthography by Segui and Grainger (1990), the strong inhibition effect exerted from higher frequency orthographic neighbor characters on the target characters did not decrease along with increasing SOA. In contrast, prime characters with frequencies lower than targets always showed smaller orthographic inhibition. Along with this dimension, it might be predicted that pseudo-character primes which are orthographically similar to target characters would not exert any inhibition on target processing; because a pseudo-character could not possess any lexical status to compete with the target. This experiment attempted to test this implication and to replicate the above two experiments with a larger set of stimulus materials. An additional prime condition with pseudo-characters was thus designed in this experiment. Ferrand and Grainger (1992) had ever used a masked prime paradigm to examine the effects of pseudo-homophonic primes and their orthographic controls on target lexical decision. Both pseudo-homophonic primes and their orthographic controls showed facilitation effects under 32 ms SOA, while only pseudo-homophonic primes exhibited facilitation effects under 64 ms SOA. They had not used non-word primes under any SOA longer than 64 ms.

Method

Participants. One hundred and fifty eight participants altogether were assigned to four groups according to the manipulation of task and SOA factors. Two groups of participants received the lexical decision task. One with 45 participants for 50 ms SOA and the other with 43 for 500 ms SOA. The other two groups (each with 36 participants) received a naming task with each SOA. They were recruited from the participant pool at National Taiwan University to participate in this experiment for partial fulfillment of course requirements. All were fluent readers of Mandarin with normal or corrected-to-normal vision.

Design and stimuli. Participants were assigned to one of four groups representing combinations of two between-subjects factors of task (lexical decision vs. naming) and SOA (50 ms vs. 500 ms). Each group of participants received the same 3 × 2 within-subjects factorial arranged materials according to the manipulation of two factors of prime type (frequency higher than target, lower than target, and pseudo-character), and orthographical relatedness (similar vs. unrelated). The design was the same as in Experiment 1 except that a new level of pseudo-character was added into the factor of prime type.

Because a new level was added into prime type, more targets were required to guarantee enough trials for each condition. Besides the original stimulus set of forty eight characters used as targets in Experiments 1 and 2, 24 more target characters were added. For each target character, six primes representing different combinations of 3 × 2 within-subjects factorial were coupled. Four of them were the same as in Experiments 1 and 2, other two constituting the pseudo-character conditions, one with orthographically similar and unrelated primes. The complete list of target characters and corresponding prime conditions are presented in the Appendix B along with character frequency. For each participant, each target character appeared just once and was preceded by only one of six different types of prime. The assignment of each target character into one of the prime conditions was counter-balanced between participants. Seventy two filler trials with target characters not restricted in medium-frequency and with the prime unrelated to the target were further included and mixed with trials of stimulus targets. This resulted in 144 trials in total for the naming task. With respect to the lexical decision task, additional 144 trials with pseudo-character targets and a different set of prime characters were constructed with a total of 288 trials. A total of 20 additional characters were also selected for practice trials.

Apparatus and procedure. The same apparatus and similar procedure as in Experiment 1 was adopted in this experiment.

All the 72 experimental trials, 72 filler trials, and additional 144 pseudo-character trials in lexical decision, were evenly and randomly divided into 12 blocks. Each block was composed of six trials from the prime conditions, one for each, and six fillers, and additional twelve pseudo-character target trials for lexical decision. Other things were the same as in Experiment 1.

Results and Discussion

As in Experiment 1, in calculating the mean RT of correct responses for each condition within each participant, those trials with RTs less than 200 ms (possible anticipation), or 2.5 standard deviations more than the mean of the condition to which the trials belonged, were treated as outliers. The percentage of outliers was 3.8 %. The re-computed mean correct RTs and mean percentages of errors across participants under different conditions of prime type ×orthographical relatedness for each group are shown in Table 2.

Insert Table 2 about here

In brief, two three-way ANOVAs with factors of SOA (50, 500 ms), prime type (higher frequency, lower frequency, pseudo-character), and orthographical relatedness (similar, control) were performed separately on the RT data for lexical decision and naming.

The ANOVA performed on lexical decision showed that the significant sources of variation were relatedness, $F_1(1, 86) = 30.15$, $MSe = 1461$, $p < .001$, $F_2\ (1, 71) = 21.28$, $MSe = 3886$, $p <.001$, prime type, $F_1(2, 172) = 35.26$, $MSe = 1258$, $p < .001$, $F_2\ (2, 142) = 34.39$, $MSe = 2421$, $p <.001$, and relatedness ×prime, $F_1(2, 172) = 20.17$, $MSe = 1346$, $p < .001$, $F_2\ (2, 142) = 21.18$, $MSe = 2179$, $p <.001$. The effect of SOA was also significant across items, $F_1(1, 86) < 1$, $F_2\ (1, 71) = 35.31$, $MSe = 1910$, $p < .001$.

Further analyses on lexical decision showed that the simple simple-main effect of relatedness was significant under the prime with higher frequency in 50 ms SOA, $F_1(1, 258) = 47.31$, $MSe = 1384$, $p < .001$, $F_2\ (1, 426) = 35.05$, $MSe = 3151$, $p <.001$; and in 500 ms SOA, $F_1(1, 258) = 17.06$, $MSe = 1384$, $p < .001$, $F_2\ (1, 426) = 14.00$, $MSe = 3151$, $p <.001$. Under the prime with lower frequency it was significant only across participants in 50 ms SOA, $F_1(1, 258) = 5.47$, $MSe = 1384$, $p < .05$, $F_2\ (1, 426) = 3.64$, $MSe = 3151$, $p > .05$; and significant both across participants and across items in 500 ms SOA, $F_1(1, 258) = 4.19$, $MSe = 1384$, $p < .05$, $F_2\ (1, 426) = 4.58$, $MSe = 3151$, $p < .05$. Under the prime with pseudo-character it was not significant in 50 ms SOA, $F_1(1, 258) < 1$, $F_2\ (1, 426) < 1$, and in 500 ms SOA, $F_1(1, 258) = 1.37$, $MSe = 1384$, $F_2\ (1, 426) < 1$.

The ANOVA performed on naming showed that the significant sources of variation were relatedness, $F_1(1, 70) = 67.67$, $MSe = 659$, $p < .001$, $F_2\ (1, 71) = 25.56$, $MSe = 3136$, $p < .001$, and prime type, $F_1(2, 140) = 5.39$, $MSe = 691$, $p < .01$, $F_2\ (2, 142) = 4.07$, $MSe = 2041$, $p < .05$, SOA, $F_1(1, 70) = 7.55$, $MSe = 48365$, $p < .01$, $F_2\ (1, 70) = 348.18$, $MSe = 2068$, $p < .001$.

Further analyses on naming showed that the simple simple-main effect of relatedness was significant under the prime with higher frequency in 50 ms SOA, $F_1(1, 210) = 8.97$, $MSe = 759$, $p < .01$, $F_2\ (1, 426) = 4.72$, $MSe = 2135$, $p <.05$; and in 500 ms SOA, $F_1(1, 210) = 12.55$, $MSe = 759$, $p < .001$, $F_2\ (1, 426) = 9.52$, $MSe = 2135$, $p <.01$. Under the prime with lower frequency it was significant in 50 ms SOA, $F_1(1, 210) = 16.04$, $MSe = 759$, $p < .001$, $F_2\ (1, 426) = 9.78$, $MSe = 2135$, $p <.01$; and in 500 ms SOA, $F_1(1, 210) = 17.63$, $MSe = 759$, $p < .001$, $F_2\ (1, 426) = 11.80$, $MSe = 2135$, $p <.01$. Under the prime with pseudo-character it was significant only in 500 ms SOA, $F_1(1, 210) < 7.71$, $MSe = 759$, $p < .01$, $F_2\ (1, 426) = 5.90$, $MSe = 2135$, $p < .05$. In contrast with that of lexical decision, the orthographic inhibition effect is easier to be obtained in naming under prime with lower frequency character or pseudo-character.

It is obvious that the prior presentations of orthographic neighbors with frequencies higher than the target always exerted inhibitions on the lexical decision responses to the target, irrespective of whether the presentation of primes were brief or long. In addition to lexical decision, whether the SOA was 50 ms or 500 ms, and whether the prime frequency was higher or lower relative to the target, the orthographic neighbors always produced inhibition on the naming response to the target. It seems that the naming task demonstrated even more robust inhibition effects from orthographic neighbors in Chinese. The same pattern of results of Experiments 1 and 2 was thus well replicated in this experiment. It also showed that pseudo-character primes did not affect target recognition while they exerted a marginally significant inhibition effect on target naming under longer prime exposure duration of 500 ms. The overall result pattern of this experiment is consistent with those from Experiment 1 and 2, except that the inhibition effect obtained on target naming under the longer prime exposure duration of 500 ms was somehow unexpected. Maybe it was due to type one false error. A replication of this experiment to verify this possibility was then needed.

Experiment 4

In the studies which used very short SOA durations of masked non-word priming procedures, Ferrand and Grainger (1992; 1993; 1994) observed the orthographic and phonological facilitation effects to present the activation process of sub-lexical orthographic information and pre-lexical phonology. While in our Experiment 3 we did not observe any orthographic facilitation effect when the primes were pseudo-characters, this may imply that at as short as 50 ms Chinese participants have passed the stage of radical processing and entered into a higher level of processing to reject the identification of the target as a lexical unit. To evaluate the inference of Ferrand and Grainger, it was necessary to explore an experimental condition under which the embedded radical of a target character was explicitly processed and kept from entering into a higher stage of lexical processing. If the free radical prime facilitates the response of the target, then the interactive activation network proposal could be confirmed. We then straightforwardly included in Experiment 4 a prime condition in which a free radical, which is embedded in the target character, was presented in isolation. In the context of a further replication of previous experiments, it was also interesting to find what would happen be if participants were demanded to explicitly process the embedded radical of a character.

It should also be noted that sublexical processing, in English, means pre-lexical analysis of substring of a word for the purpose of converting its graphemes into phonology and then mapping to a lexical level unit. But for Chinese, how would it be to define a pre-lexically sub-lexical process when we have known it is without any orthographically pre-defined phonology to mediate the lexical process? A radical is usually a constituent unit of a character. When standing alone in isolation with size adjusted as a normal character, it also could play a role as a character with its specific semantic meaning and pronunciation. The pronunciation of a radical standing as a character is usually unrelated with those pronunciations of characters embedding that particular radical. The consistency among pronunciations of different characters embedding the same radical is, in general, low (Liu, Sue, & Chen, 2001). This suggests that too much pre-lexical processing of embedded radicals would be harmful to the process of target character processing. Pre-lexical processing of a radical will be logically restricted within a very shallow level of orthographic analysis. It should not enter into a higher level of linguistic transformation. If the radical has been well processed to an extent that its phonological information could be possibly activated, then conflict results inevitably. This means that it may be hard to observe a reliable facilitation effect of embedded radicals on character naming.

Method

Participants. One hundred and seventeen participants altogether were randomly assigned to four groups according to the manipulation of the Task and SOA factors. Two groups of participants (30 and 28) received a lexical decision task with 50 or 500 ms SOA, while the other two groups of participants (31 and 28) received a naming task with 50 or 500 ms SOA. They were recruited from the same participant pool as in Experiment 3. All were fluent readers of Mandarin with normal or corrected-to-normal vision.

Design and stimuli. Participants were evenly assigned into one of four groups representing combinations of two between-subjects factors of task (lexical decision vs. naming) and SOA (50 ms vs. 500 ms). Each group of participants received the same 4 × 2 within-subjects factorial arranged materials according to the manipulation of two factors of prime type (frequency higher than target, lower than target, pseudo-character, and isolated radical), and orthographical relatedness (similar vs. unrelated). The design was the same as in Experiment 3 except that a new level of isolated radical was added into the factor of prime type.

The stimulus set of 72 characters as targets used in Experiment 3 was adopted in this experiment. For each target character, eight primes representing different combinations of 4 × 2 within-subjects factorial were coupled. Six of them were the same as in Experiment 3, otherwise two were isolated radical conditions, one with orthographic similarity (right half part radical of the target character) and the other unrelated radical control. For each participant, each target character appeared just once and was preceded by only one of eight different types of prime. The assignment of each target character into the different prime conditions was counter-balanced between participants. The same seventy-two filler trials used in Experiment 3 were also adopted to mix with experimental stimulus trials. This finished with 144 trials in total for the naming task. With respect to the lexical decision task, the same 144 trials with pseudo-character targets used in Experiment 3 were also adopted to end up with 288 trials in total. Twenty additional characters were also selected for practice trials.

Apparatus and procedure. The same apparatus and similar procedure of Experiment 3 were adopted in this experiment. For the prime condition with an isolated radical, the isolated radical was displayed in its normal size (radical size) as is embedded in a character, instead of in the character size.

All the 72 experimental trials, 72 filler trials, and additional 144 pseudo-character trials in lexical decision, were evenly and randomly divided into 9 blocks. Each block was composed of eight trials from different prime conditions, one for each, and eight fillers, and additional 16 pseudo-character target trials for lexical decision.

Results and Discussion

The data analysis was similar as in Experiment 3. The computed mean correct RTs and mean percentages of errors across participants under different conditions of prime type ×orthographical relatedness for each group are shown in Table 2.

Insert Table 2 about here

Two three-way ANOVAs with factors of SOA (50, 500 ms), prime type (frequency higher, lower, pseudo-character, isolated radical), and orthographical relatedness (similar, control) were performed separately on the RT data for lexical decision and naming.

The ANOVA performed on lexical decisions showed that the significant sources of variation were prime type, $F_1(3, 168) = 14.16$, $MSe = 1966$, $p < .001$, $F_2\ (3, 213) = 12.91$, $MSe = 5910$, $p <.001$, and relatedness ×prime, $F_1(3, 168) = 6.15$, $MSe =2682$, $p < .001$, $F_2\ (3, 213) = 6.33$, $MSe = 6691$, $p <.001$. The effect of SOA was also significant across items, $F_1(1, 56) < 1$, $F_2\ (1, 71) = 7.90$, $MSe = 4361$, $p <.01$.

Further analyses on lexical decision showed that the simple simple-main effect of relatedness was significant, indicating an inhibition effect as shown in Table 2, under the prime with higher frequency in 50 ms SOA, $F_1(1, 224) = 9.84$, $MSe = 2362$,

$p < .01$, F_2 (1, 568) = 10.15, *MSe* = 5307, $p <.01$; and in 500 ms SOA, F_1(1, 224) = 5.98, *MSe* = 2362, $p < .05$, F_2 (1, 568) = 7.00, *MSe* = 5307, $p <.01$. Under primes with radicals in isolation it was significant, indicating an orthographic facilitation effect with an effect size far weaker than that of the inhibition effect under the prime with higher frequency, at 50 ms SOA only marginally across participants, F_1(1, 224) = 3.55, *MSe* = 2362, $p = .05$, F_2 (1, 568) < 1, and at 500 ms SOA only across items, F_1(1, 224) = 2.85, *MSe* = 2362, $p < .1$, F_2 (1, 568) = 8.51, *MSe* = 5307, $p <.01$.

The ANOVA performed on naming showed that the significant souces of variation were relatedness, F_1(1, 57) = 27.86, *MSe* = 1097, $p < .001$, F_2 (1, 71) = 13.61, *MSe* = 4448, $p < .001$, prime type, F_1(3, 171) = 4.30, *MSe* = 1117, $p < .01$, F_2 (3, 213) = 2.77, *MSe* = 3333, $p < .05$, and relatedness × prime, F_1(3, 171) = 5.40, *MSe* = 840, $p < .01$, F_2 (3, 213) = 2.47, *MSe* = 4188, $p <.1$. The effect of SOA was also significant across items, F_1(1, 57) < 1, F_2 (1, 71) = 8.47, *MSe* = 2782, $p < .01$.

Further analyses on naming showed that the simple simple-main effect of relatedness was significant, indicating an inhibition effect as shown in Table 2, under the prime with higher frequency in 50 ms SOA, F_1(1, 228) = 16.56, *MSe* = 904, $p < .001$, F_2 (1, 568) = 4.59, *MSe* = 5546, $p <.05$; and in 500 ms SOA, F_1(1, 228) = 13.91, *MSe* = 904, $p < .001$, F_2 (1, 568) = 4.87, *MSe* = 5546, $p <.05$. Under the prime with lower frequency it was significant in 50 ms SOA only across participants, F_1(1, 228) = 4.12, *MSe* = 904, $p < .05$, and significant in 500 ms SOA, F_1(1, 228) = 11.22, *MSe* = 904, $p < .01$, F_2 (1, 568) = 4.51, *MSe* = 5546, $p <.01$.

It is obvious that the prior presentation of orthographic neighbors with frequencies higher than targets always exerts inhibitions on the lexical decision responses to the target, irrespective of whether the presentation of primes were short or long. In addition to lexical decision, whether the SOA was 50 ms or 500 ms, and whether the prime frequency was higher or lower relative to the target, the orthographic neighbors always produced inhibition on the naming response to the target. It seems that naming task demonstrated even more robust inhibition effects from orthographic neighbors in Chinese. The experiment replicated the same result pattern of Experiments 1, 2, and 3. Priming with a pseudo-character exerted no effect at all as expected. It also showed that the priming with a component radical in isolation did facilitate the recognition of target characters, while it exerted no effect on character naming at all. It is compatible with the aforementioned argument that it's hard to observe a reliable facilitation effect of radicals on the naming of embedding characters. A possible explanation is that naming task demands phonology that participants have to quit the processing of radical earlier to prevent conflict between the pronunciation activated from the embedded radical and that from the whole character. The result that the phonetic radical facilitation effect could not be observed on naming is in contradiction to that of Flores d' Arcais, et al. (1995). They found that earlier exposure of the phonetic radical produced facilitation of the Kanji naming response, which was stronger at the 180-ms SOA than at the 60-ms SOA. This facilitation effect is difficult to be evaluated because the prime in the control condition they used was a configuration of fragments composed of pieces of the strokes randomly selected from the target character. Nevertheless, it also remains possible in the present experiment that lexical decision may involve more than naming in analyzing a character into components and inducing the facilitation effect from radical components.

General Discussion

In the four experiments, we demonstrated that orthographic neighbor primes exert inhibitory effects on target lexical decision and naming. Moreover, the relative frequency of the prime and the target also played an important role in the time-course of inhibition. In Experiment 1 and 2, three factors of orthographic similarity, neighbor frequency, and SOA were manipulated to observe the possible effects of orthographic priming on lexical decision and naming. Experiments 1 and 2 show that when the SOA was as short as 50 ms, only higher frequency orthographic neighbor primes produced inhibitory effects on the target processing. When the SOA was long enough, both higher frequency orthographic neighbor primes and lower frequency ones produced inhibition on the target processing. These results were different from those observed by Segui and Grainger (1990) using French. In their study, only higher frequency orthographic primes exhibited inhibition effects at 60 ms SOA; however when the SOA was extended to 350 ms this higher frequency orthographic inhibition effect disappeared and the lower frequency orthographic inhibition effect was manifested. In short, for a deep orthography like Chinese, a higher frequency orthographic neighbor prime would rapidly produce an inhibition effect and this effect would last when the SOA was extended. For a shallow orthography like French, a higher frequency orthographic neighbor prime would also produce an inhibition effect when the SOA was short but would lose its inhibitory effect when the SOA is long. The difference between these two orthographies is interesting and needs to be discussed.

A possible interpretation is as follows. For a short prime presentation, only higher frequency primes would produce a level of activation high enough to inhibit the processing of the orthographic neighbor target. For a prime presentation long enough, both higher frequency primes and lower frequency primes would produce activation levels high enough to inhibit the processing of their orthographic neighbor targets. This is applicable for any orthography except that phonology will play an important role as well in a shallow alphabetic orthography. Because in shallow orthographies, phonology covaries with orthography to a great extent. When an SOA is long enough, the phonology of primes would be sufficiently activated for words of higher frequency, thus produces on the processing of the orthographic neighbor target a facilitatory effect which compensates the inhibition resulting from orthographic similarity. In Chinese, phonology does not covary with orthography. There is no way to pronounce a character with certainty before it is recognized. For instance, with an identical stem or phonetic radical, 也 (pronounced as /ye3/, translated as 'besides'), embedded in, there are many different but orthographically similar, or neighborhood, characters with different pronunciations, 地 (/di4/, 'earth', with the left part radical pronounced as /tu3/, translated as 'soil'), 池 (/chi2/, 'pond', with the left radical as /sui3/, 'water'), 馳 (/chi2/, 'run', with the left radical as /ma3/, 'horse'), and 他 (/ta1/, 'he', with the left radical as /jun2/, 'person'), etc.. It is also noted that a total number of characters known by a college student is around five thousands in general while the total number of different pronunciations with tone is only around 1400. It is thus obvious that Chinese orthography does not bind phonology. There exists no obligatory phonological process in lexical identification to produce any facilitation from phonological priming. Phonology for some people reading Chinese orthography might even be semantically mediated. For instance, the character 行 is pronounced as /hang2/ when it combines with the character 列 to form a compound word 行列 (means 'row and column'), and pronounced as /hsin2/ when it combines with the character 進 to form another word 進行 (means 'progression'). In normal reading of the traditional Mandarin Chinese, there are more than 900 characters each with more than one pronunciation depending on different semantic situations encountered.

The first two experiments were replicated in Experiment 3. In addition, Experiment 3 included a new prime condition of pseudo-characters. In Experiment 3, if pseudo-character primes exert inhibition, the notion of within-level inhibition among lexical units, as stated in the modified interactive activation model proposed by Ferrand and Grainger (1992), would encounter difficulties. Because a pseudo-character possesses no lexical status, if a pseudo-character prime does produce inhibition the phenomenon of interference might be classified to be within a perceptual, rather than a linguistic, domain. Phenomena in these two different domains will be affected by different variables. Pseudo-character primes did not exert any inhibition in Experiment 3. This is not incompatible since neighbor character frequency is a crucial factor in a linguistic domain.

In addition to replicating Experiments 1, 2, and 3, Experiment 4 further included a new condition of free-radicals presented in isolation. In Experiment 4, the priming with a component radical in isolation exerted a significant effect of facilitation, instead of inhibition, on the lexical decision process of targets, while exerting no effect on character naming at all. According to the notion of an interactive activation model, a bottom-up process and a top-down process are both involved. A bottom-up process is defined as a “facilitation link” drawing from the radical level to the character level. A top-down process could be imagined as a facilitation link coming from a character level down to a feature level. The results are compatible with this notion. To explain why the radical facilitation could not be observed with naming, a possible explanation is that naming tasks demand phonology, and participants have to bypass the radical processing earlier to prevent conflict between the pronunciation activated from the embedded radical and that from the whole character. It seems that this experiment provides valuable evidence to clarify some questions raised in the thinking of priming paradigms.

Based on the results from the above four experiments, the conclusions could be summarized as follows. First, the orthographically similar character prime produces an inhibition effect on the naming and lexical decision of the moderately high freqency target character. The relative frequency of the prime character is a crucial variable. Second, the SOA is also an important factor moderating the variable of prime character frequency. When the SOA is short, only the higher frequency orthographic prime characters would inhibit the naming and lexical decision processes of targets. When the SOA is extended long, orthographic prime characters of both higher frequency and lower frequency inhibit the naming and lexical decision processes of targets. This is different from the results of Grainger’ s studies on French (e.g., Segui & Grainger, 1990). When the SOA is extended long the higher frequency orthographic prime word loses its inhibition effect on the lexical decision of targets. Third, no mater whether the SOA is short or long, orthographic pseudo-characters do not exert any effect on the naming or lexical decision processing of targets. Fourth, in contrast, no mater whether the SOA is short or long, priming with the right-half radical of targets exerts a significant facilitation effect on the lexical decision of targets while it exerts no effect on the naming of targets.

Some implications will be drawn. It is easier for Chinese than a shallow script like French to observe orthographic inhibition effects on processing neighbor characters or words. In Experiment 4, some points are worth noticing. First, presenting an embedded radical in isolation exerted a significant facilitation effect on the lexical decision of the subsequent target. Second, presenting an orthographic character embedding a shared radical exerted a significant inhibition effect on the lexical decision and naming of the subsequent target. Third, presenting an orthographic pseudo-character embedding a shared radical did not exert any effect on the lexical decision and naming of the subsequent target. It may then be elaborated as follows. Though processing an embedded radical in isolation in advance would facilitate the subsequent target recognition as observed under the condition of radical priming, processing a character or pseudo-character which embedded that particular radical would not produce any facilitation effect. Obviouly, the participants did not process the radical embedded in the characters or pseudo-characters they encountered. It seemed that they drove rushly through into the lexical unit level, skipping the detail processing of the radical unit level. At very early time they must have correctly identified the character encountered. This is indicated by an inhibition on the processing of neighbor characters as observed under the condition of character priming. Had the embedded radical ever been processed before the prime character was identified, it would to be possible, in some shorter durations of SOA, to observe a facilitation effect for lower frequency orthographic neighbors. In fact, we did not find any facilitation effect under this condition.

It should also be noted that orthographic facilitation effects observed in alphabetic orthographies were mostly based on studies using pseudo-word priming. In contrast, we did not find any orthographic facilitation effect in Chinese pseudo-character priming. It is suggested that the time needed to recognize a Chinese character (or lexical unit) is much shorter than the time needed to recognize an alphabetic word. At very early time the pseudo-character encountered must have been correctly rejected as a character. Therefore, no inhibition effect on the processing of orthographic neighbor target characters could be observed under the condition of pseudo-character priming because a pseudo-character possesses no lexical status. Moreover, had the embedded radical ever been processed during pseudo-character processing, a facilitation effect on target processing ought to be observed just as that shown in studies on alphabetic orthographies.

Other related studies are worth mentioning here. Empirical evidence tends to argue against the pre-lexical or pre-semantic phonology in identifying Chinese characters. Liu, Wu, and Chou (1996) found that in Chinese the character frequency effect is larger in naming than in lexical decisions. It was assumed that there was no pre-lexical phonology in character identification. The phonology in naming is thus produced post-lexically. Using a general linear model to fit the latencies of lexical decision, naming, and lexical naming (a specially designed task which includes pseudo-characters and demands subjects to name characters or to signify pseudo-characters), an additive model was proposed. This means that the variation components of lexical identification, post-lexical decision, and post-lexical phonology to account for the frequency effects of different tasks could be orthogonally separated. Besides, there was no regularity effect found in character lexical decisions (Wu, Chou, & Liu, 1994). Using Japanese Kanji and Katakana to compute the relative frequency effects in naming and lexical decision, Hino and Lupker (1998) found the sizes of frequency effects for Kanji (a deep script) were comparable in the tasks of lexical decision and naming, while for Katakana (a shallow script) the frequency effect in the naming was smaller than that in the lexical decision. This is in line with the results of Liu and colleagues in their studies using Chinese characters (cf. Liu, Wu, & Chou, 1996). These results are consistent with those from studies of the orthographic depth hypothesis (cf. Frost, 1994; Frost & Bentin, 1992; Frost, Katz, & Bentin, 1987; Katz & Feldman, 1983; Katz & Frost, 1992).

On the other hand, there are some studies which propose that, similar to alphabetic systems, the phonological activation is a pre-lexical or at-lexical automatic process in the recognition of Chinese characters (e.g., Cheng, 1992; Cheng & Shih, 1988; Perfetti & Zhang, 1991, 1995, 1996). Their evidence came from the finding of homophonic priming effects on lexical decision and naming. Cheng (1992) reported a significant homophonic priming facilitation effect on lexical decision to support his obligatory phonological recording view of Chinese character recognition. Perfetti and Zhang (1991) found that homophonic primes, compared to semantic primes, showed greater facilitation effects on naming target characters. Based on these studies it was claimed that the character identification is accompanied with the activation of phonology automatically and pre-semantically (Perfetti & Zhang, 1996).

This view of universal phonology was also supported by further studies (e.g., Perfetti & Tan, 1998 ; Tan & Perfetti, 1997). In the study of Perfetti and Tan (1998), they attempted to demonstrate the time courses of activation of orthographic and phonological information in experiments using primed naming tasks with SOAs varying from 43 ms to 180 ms. When the SOA was 43 ms graphic (orthographically similar) primes produced facilitation on target naming. When the SOA was 57 ms, this graphic facilitation effect disappeared and turned out to be inhibitory, and a strong homophonic facilitation effect appeared. When the SOA was 85 ms, a greater graphic inhibition showed, homophonic primes kept maintaining facilitation, and semantic primes began to show facilitation. When the SOA was extended to be 115 ms, both semantic and homophonic primes exerted a comparable amount of facilitation effect. This time-course pattern, linked with the result of Experiment 4 (180 ms SOA) in Perfetti and Zhang (1991), thus portrayed an ideal picture to support their pre-semantic phonology claim. Neither in Perfetti and Tan (1998) nor in Perfetti and Zhang (1991) was there any graphic inhibition effect reported when the SOA was longer than 115 ms.

In an attempt to examine Perfetti's studies, Wu and colleagues (Wu & Chen, 2000; Wu & Chou, 2000) conducted four experiments using traditional Chinese characters. Not only the factors of prime type and SOA were manipulated as Perfetti's naming studies, but also (1) target frequency was manipulated, (2) the SOA was manipulated between-subjects in an experiment and within-subjects in another, and (3) both tasks of lexical decision and naming were evaluated. The results are summarized as follows. (1) A substantial semantic facilitation effect was observed under all conditions for targets of low frequency. (2) A homophonic facilitation effect was observed only under certain conditions of SOA for targets of low frequency. (3) Whenever a homophonic facilitation effect was observed a greater facilitation effect of semantic priming was observed. (4) A long lasting graphic inhibition effect was obviously observed on target characters of high frequency, both in naming and lexical decisions.

Chen and Shu (2001) re-conducted the experiment of Perfetti and Tan (1998), with the same materials (of simplified Chinese characters), design, and computer program. Different subject samples from Hong Kong and from mainland China were recruited. Though their study was without manipulation of target character frequency, they obtained results well in agreement with the studies of Wu and colleagues (Wu & Chen, 2000; Wu & Chou, 2000). For the participants from Beijing, semantic activation (facilitation) appeared at all SOA levels. A significant homophonic priming facilitation was only obtained at the SOA of 57 ms, and a reliable graphic inhibition was found across different SOAs. For the participants from Hong Kong, a significant early semantic activation was observed at the SOA of 57 and 85 ms. No reliable homophonic priming effect was found in any SOA, and a reliable graphic inhibition appeared at the SOA of 85 ms.

It is now worth elaborating on the incongruent results from different studies concerning possible factors affecting the processing of orthographic information. While neither Cheng (1992) nor Perfetti and Zhang (1991) found any observable effect of orthographic priming, Perfetti and Tan (1998) did report some facilitation effects of orthographic priming when the SOA was 43 ms, some inhibition effects when SOA was increased to 57ms and 85ms, and no effect when SOA was longer than 115 ms. Perfetti and Zhang (1991) also found no effect of orthographic priming when SOA was 180 ms. On the other hand, using fluent Mandarin speaking participants from Taipei, Wu and his colleagues (Wu & Chen, 2000; Wu & Chou, 2000) obtained a substantial effect of inhibition from orthographic priming on higher frequency target either in lexical decision or in naming when the SOA was from 50 ms to 1000 ms. In the replication study using the same materials of Perfetti and Tan (1998), Chen and Shu (2001) did not observe any graphic facilitation effect as found by Perfetti and Tan (1998). Instead, Chen and Shu (2001) observed a reliable graphic inhibition effect in their fluent Mandarin speaking participants from Beijing. Perhaps the participants from Hong Kong were not as fluent Mandarin speakers, the graphic inhibition effect was still observed while was not so reliable. The results of Chen and Shu (2001) are compatible with the results from Wu and his colleagues (Wu & Chen, 2000; Wu & Chou, 2000).

Using a masked priming procedure Shen and Forster (1999) manipulated prime type (orthographic, homographic, orthographically homographic, and control) to observe their effect on target naming and lexical decision. The SOA was fixed at 50 ms. A quite different result was obtained. Both orthographic prime and phonological prime exerted facilitation effects on the target naming, while only orthographic priming exerted a facilitation effect on the target lexical decision. However, their conclusion encountered some serious confounding. Though without clear description of the procedure about their stimuli balancing, from the degree freedom of *F* values in their by-items analyses it can be inferred that they did not apply any between-subjects counter-balance procedure on their stimuli for different prime types. This means that each target character had repeatedly appeared for many times for each participant. A repetition priming facilitation effect should have resulted to confound with their finding. Their conclusion was thus not convincing.

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Table 1

Mean correct latencies in milliseconds as a function of task, graphemic similarity, prime type, and SOA for Experiment 1 and 2

Task	SOA	Higher Frequency		Lower Frequency	
		GS	Control	GS	Control
Experiment 1					
LDT					
	50 ms	504 (9.3)	435 (3.0)	442 (3.3)	435 (2.0)
	500 ms	516 (8.7)	470 (2.7)	463 (1.7)	458 (3.0)
Naming					
	50 ms	517 (1.3)	479 (1.0)	508 (2.3)	490 (1.3)
	500 ms	498 (1.0)	469 (4.0)	490 (3.3)	464 (0.3)
Experiment 2					
LDT					
	1000 ms	525 (4.6)	478 (4.2)	509 (0.8)	470 (0.8)
Naming					
	1000 ms	551 (1.3)	522 (2.1)	546 (1.7)	519 (0.8)

Note: Percentages of errors are given in parentheses.
SOA = Stimulus Onset Asynchrony,
GS = Graphemically Similar.

Table 2

Mean correct latencies in milliseconds as a function of task, graphemic similarity, prime type, and SOA for Experiment 3 and 4

Task	SOA	Higher Frequency		Lower Frequency		Pseudo-character		free radical	
		GS	Control	GS	Control	GS	Control	GS	Control
Experiment 3									
LDT									
	50 ms	535 (11.3)	481 (3.0)	482 (4.4)	463 (3.0)	486 (4.3)	489 (5.2)		
	500 ms	506 (7.0)	473 (2.9)	474 (2.7)	457 (1.7)	456 (4.8)	465 (2.5)		
Naming									
	50 ms	536 (3.2)	517 (2.1)	528 (1.4)	502 (1.4)	518 (1.6)	510 (1.6)		
	500 ms	475 (2.8)	452 (2.8)	475 (2.6)	448 (2.6)	465 (1.9)	447 (3.7)		
Experiment 4									
LDT									
	50 ms	503 (12.6)	463 (1.9)	457 (4.1)	440 (1.9)	469 (6.3)	472 (4.8)	433 (2.4)	457 (4.1)
	500 ms	490 (6.7)	458 (2.4)	441 (3.2)	443 (2.0)	462 (7.5)	449 (6.8)	439 (2.8)	461 (3.6)
Naming									
	50 ms	489 (2.5)	458 (1.8)	471 (2.9)	455 (1.4)	467 (1.4)	455 (0.7)	453 (1.1)	455 (0.7)
	500 ms	487 (2.0)	458 (2.0)	482 (1.2)	455 (0.8)	482 (0.8)	472 (0.8)	464 (0.4)	459 (0.8)

Note: Percentages of errors are given in parentheses. SOA = Stimulus Onset Asynchrony, GS = Graphemically Similar.

Appendix A
Experimental Materials in Experiment 1 and 2

Target			Higher Frequency Prime						Lower Frequency Prime					
			Neighbor			Control			Neighbor			Control		
C	NS	CF	C	NS	CF	C	NS	CF	C	NS	CF	C	NS	CF
儀	15	105	議	20	398	歡	22	392	蟻	19	13	蹦	18	13
奶	5	107	仍	4	381	依	8	379	扔	5	12	妃	6	12
顏	18	121	領	14	317	較	13	314	頒	13	11	滄	13	11
刺	8	131	制	8	469	拉	8	473	剖	10	11	畔	10	11
刊	5	89	利	7	837	何	7	841	划	6	11	仕	5	11
硬	12	102	便	9	1105	相	9	1045	哽	10	10	栩	10	10
攻	7	120	改	7	435	球	11	432	孜	7	10	灶	7	10
牠	7	133	地	6	2613	你	7	2717	弛	6	10	朴	6	10
稅	12	127	說	14	3061	得	11	3140	蛻	13	9	貂	12	9
封	9	129	對	14	2092	裡	13	2101	吋	6	9	汝	6	9
訂	9	89	打	5	885	物	8	879	汀	5	9	札	5	9
核	10	140	孩	9	468	科	9	461	骸	16	8	諫	16	8
仔	5	81	好	6	1863	所	8	1943	籽	9	8	趴	9	8
股	8	87	設	11	373	跟	13	373	骰	14	7	滷	14	7
堆	11	96	推	11	270	項	12	268	椎	12	7	琢	12	7
猜	11	77	清	11	638	接	11	635	倩	10	7	捆	10	7
估	7	80	點	17	1086	間	12	1104	玷	9	7	炳	9	7
悄	10	84	消	10	394	統	11	387	俏	9	7	拷	9	7
乾	11	148	吃	6	493	即	7	501	屹	6	7	旭	6	7
勤	13	95	動	11	1383	現	11	1372	勳	16	6	擄	16	6
織	18	112	識	19	344	隨	16	344	幟	15	6	嫻	15	6
朗	10	105	明	8	1000	位	7	992	朔	10	6	畝	10	6
悟	10	99	語	14	344	派	9	341	晤	10	6	栓	10	6
恨	9	89	很	9	1126	將	11	1178	垠	9	6	恤	9	6
抬	8	85	治	8	369	料	10	371	冶	7	6	吠	7	6
幼	5	91	功	5	403	呢	8	387	肋	6	6	佣	7	6
殘	12	133	錢	16	361	據	16	361	棧	12	5	鈍	12	5
帳	11	95	張	11	606	結	12	605	悵	11	5	酗	11	5
雪	11	145	電	13	806	感	13	801	霏	16	4	壑	17	4
狗	8	89	夠	11	251	停	11	252	駒	15	4	諛	15	4
略	11	150	路	13	762	像	14	780	酪	13	4	睦	13	4
彼	8	112	被	11	692	師	10	698	跛	12	4	湄	12	4
吹	7	109	次	6	794	許	11	787	炊	8	4	歿	8	4
煩	13	118	須	12	334	備	12	336	頊	12	2	脛	11	2
坦	8	111	但	7	1529	法	8	1452	靼	14	2	膈	14	2
輪	15	115	論	15	551	數	15	558	綸	14	2	滬	14	2
週	12	113	調	15	438	輕	14	436	碉	13	2	蜈	13	2
括	9	103	活	9	739	別	7	735	蛞	12	2	軼	12	2
吧	7	139	把	7	1260	從	11	1233	耙	10	2	陝	10	2
抵	8	88	低	7	302	般	10	306	祗	10	2	悌	10	2
妙	7	134	沙	7	251	供	8	247	眇	9	2	埂	10	2
拍	8	145	怕	8	290	投	7	289	珀	9	2	洵	9	2
洛	9	90	格	10	375	紅	9	375	恪	9	2	邵	8	2
折	7	136	新	13	892	加	5	906	昕	8	2	杵	8	2
揮	12	136	運	13	514	強	11	531	諢	16	1	觭	15	1
衝	15	139	術	11	404	程	12	411	衖	12	1	愫	13	1
借	10	111	錯	16	254	衛	15	257	腊	12	1	嵋	12	1
探	11	146	深	11	487	該	13	485	琛	12	0	稈	12	0

Note: C = character, NS = number of strokes, CF = character frequency per million.

Appendix B
Experimental Materials in Experiment 3 and 4

		Higher Freq. Prime				Lower Freq, Prime				Pseudo-Character	
Target		Neighbor		Control		Neighbor		Control		Neighbor	Control
C	CF	C	CF	C	CF	C	CF	C	CF	C	C
儀	105	議	398	戰	363	蟻	13	蹦	13	[得儀]	[鋅淬]
奶	107	仍	381	化	715	扔	12	朴	10	[坡奶]	[狼研]
顏	121	領	317	隨	344	頒	11	滄	11	[彩顏]	[鋅徑]
刺	131	制	469	拉	473	剖	11	嫻	6	[彩刺]	[狼岳]
刊	89	利	837	何	841	划	11	畔	11	[襟刊]	[幅汗]
硬	102	便	1105	相	1045	哽	10	仕	11	[好硬]	[町怡]
攻	120	改	435	依	379	孜	10	栩	10	[惚攻]	[吠拴]
牠	133	地	2613	你	2717	弛	10	趴	8	[稻牠]	[得作]
稅	127	說	3061	得	3140	蛻	9	貂	9	[襟稅]	[說祕]
封	129	對	2092	知	1328	吋	9	捆	7	[耕封]	[說犹]
訂	89	打	885	卻	959	汀	9	峙	6	[轍訂]	[吠詰]
核	140	孩	468	料	371	骸	8	畝	6	[歧核]	[碑作]
仔	81	好	1863	此	1395	籽	8	札	9	[棵仔]	[仁犯]
股	87	設	373	即	501	骰	7	拷	7	[轍股]	[好泠]
堆	96	推	270	項	268	椎	7	琢	7	[映堆]	[狼溫]
猜	77	清	638	接	635	倩	7	滷	7	[豹猜]	[襟桐]
估	80	點	1086	如	1809	玷	7	忡	2	[好估]	[燃扔]
悄	84	消	394	取	564	俏	7	祛	0	[好悄]	[河誌]
乾	148	吃	493	記	419	屹	7	揹	0	[斛乾]	[彩村]
勸	91	動	1383	間	1104	勳	6	擢	2	[鼬勸]	[飯噹]
織	112	識	344	邊	534	幟	6	躐	1	[軨織]	[敲鴿]
朗	105	明	1000	個	4028	朔	6	舫	4	[豹朗]	[鋅仙]
悟	99	語	344	師	698	唔	6	埂	2	[旗悟]	[豬犹]
恨	89	很	1126	理	1269	垠	6	倔	7	[稻恨]	[狼稀]
抬	85	治	369	呢	387	冶	6	邵	2	[坡抬]	[襟犽]
幼	91	功	403	加	906	肋	6	叱	9	[綿幼]	[即取]
殘	133	錢	361	跟	373	棧	5	鈍	5	[碑殘]	[詢甜]
帳	95	張	606	這	4972	悵	5	緋	4	[河帳]	[得種]
楊	144	場	669	結	605	煬	5	嵋	1	[好楊]	[晴姬]
狗	89	夠	251	停	252	駒	4	酗	5	[殤狗]	[虞磨]
略	150	路	762	部	855	酪	4	琨	4	[犢略]	[睛蛹]
彼	112	被	692	特	673	跛	4	杵	2	[竣彼]	[陳柚]
吹	109	次	794	位	992	炊	4	佣	6	[怡吹]	[殆缸]
煩	118	須	334	備	336	預	2	湄	4	[好煩]	[動郵]
坦	111	但	1529	所	1943	靼	2	炳	7	[礪坦]	[珠沌]
輪	115	論	551	數	558	綸	2	膘	2	[襟輪]	[飯理]

Note: C = character, CF = character frequency per million.
A pseudo-character was constructed from a pair of two characters in square brackets with the left radical from the left character and the right radical from the right character.

Appendix B
Experimental Materials in Experiment 3 and 4 (Continues).

Target		Higher Freq. Prime				Lower Freq, Prime				Pseudo-Character	
		Neighbor		Control		Neighbor		Control		Neighbor	Control
C	CF	C	CF	C	CF	C	CF	C	CF	C	C
週	113	調	438	程	411	碉	2	睦	4	[建週]	[豬詢]
括	103	活	739	物	879	蛞	2	恤	6	[綴括]	[呵指]
吧	139	把	1260	法	1452	耙	2	歿	4	[礪吧]	[種行]
抵	88	低	302	紅	375	祗	2	洵	2	[耕抵]	[河蛭]
妙	134	沙	251	供	247	眇	2	吠	6	[知妙]	[河桅]
拍	145	怕	290	般	306	珀	2	陝	0	[眼拍]	[碑缺]
洛	90	格	375	球	432	恪	2	栓	6	[疏洛]	[級報]
折	136	新	892	信	858	昕	2	妃	12	[行折]	[瑱統]
揮	136	運	514	強	531	諢	1	觭	1	[襟揮]	[俞煎]
徑	94	經	1603	從	1233	脛	2	愫	1	[狼徑]	[喝浹]
借	111	錯	254	統	387	腊	1	螟	2	[河借]	[喝誌]
探	146	深	487	該	485	琛	0	稈	0	[碑探]	[軀師]
幅	99	福	277	群	233	蝠	2	戢	3	[隔幅]	[豬狐]
敬	118	教	1178	就	2668	赦	11	鄆	0	[轍敬]	[飯銀]
敦	76	政	913	認	615	攷	0	塚	2	[暢敦]	[桶煤]
脈	72	派	341	規	311	扼	0	拭	12	[賺脈]	[稻狗]
扮	71	份	253	投	289	枌	0	汝	9	[襟扮]	[晴戰]
釣	98	的	26642	裡	2101	趵	0	悌	2	[弘釣]	[詢餌]
伸	151	神	784	任	605	砷	2	旭	7	[牧伸]	[狂往]
析	76	近	561	保	591	斫	0	帙	0	[牧析]	[珠貶]
杜	73	社	536	則	560	牡	5	阮	14	[疏杜]	[順怡]
雞	94	難	678	機	942	錐	8	黠	2	[陳雞]	[彩模]
坡	74	破	290	連	442	皶	0	祀	7	[牧坡]	[好拴]
鄰	90	都	2048	影	586	鄔	3	磺	2	[就鄰]	[軀諫]
孔	81	亂	265	比	739	軋	10	仆	4	[軡孔]	[呆卉]
副	126	到	3513	現	1372	劙	6	貶	10	[訊副]	[豬桐]
頗	75	類	378	滿	544	頦	1	榛	2	[轍頗]	[彩浣]
額	129	顯	324	雖	474	顱	5	螭	0	[舒額]	[駝詢]
淨	104	靜	269	輕	436	崢	3	婢	10	[糠淨]	[晴徨]
梅	73	海	754	許	787	誨	5	綵	2	[鐵梅]	[蟻修]
欲	93	歡	392	較	314	歛	25	悖	4	[糠欲]	[轍吱]
斜	85	科	461	根	424	蚪	5	皎	2	[郵斜]	[豬詰]
姓	125	性	980	非	582	甦	6	炕	2	[蚊姓]	[種佃]
勤	95	助	279	隊	306	勦	2	訣	4	[致勤]	[碑緬]
惱	82	腦	268	衛	257	瑙	10	豌	2	[碑惱]	[襟錘]
柯	68	河	252	待	287	蚵	2	沱	2	[町柯]	[幅洋]

Note: C = character, CF = character frequency per million.
A pseudo-character was constructed from a pair of two characters in square brackets with the left radical from the left character and the right radical from the right character.

漢字辨認與唸讀裡的形似促發字相對出現頻率效果

吳瑞屯　　　　陳欣進

國立台灣大學心理系

摘　要

最近的研究一再顯示語意促發對漢字的辨認與唸讀有穩定的增快效果，但同音促發卻對認字沒有穩定的增快效果或沒有效果，反駁了流行的認為漢字辨識或提取語義之前一定介入語音處理歷程的看法。這些研究同時闡明了某些情況下穩定的形似促發之抑制效果。本文提出四個更進一步的實驗，希望深入探討形似促發字之抑制效果。目標字設定在中高頻字，採用非遮蔽促發程序的認字及唸字作業。實驗一操弄促發字之相對出現頻率、字形相似與否、及促發字呈現時間，測量反應時間。結果在兩種作業下都發現，較目標字更高頻的形似促發字在呈現時間為 50 及 500 毫秒時皆產生明顯的抑制作用。實驗二把實驗一的促發字呈現時間延長到 1000 毫秒，結果除了較目標字更高頻的形似促發字仍維持明顯的抑制作用外，較目標字更低頻的形似促發字也產生抑制作用效果。實驗三採用了與實驗一相同的設計，但加入了假字促發字的情況，結果重複了實驗一的結果，但假字不產生任何顯著效果。實驗四採用了實驗三相同的設計，同時加入了單獨部件出現的額外促發情境。結果複製了實驗三的結果，而且，單獨出現目標字內含部件的促發情況對目標字認字產生增快作用，但對唸字則不產生顯著影響效果。這些結果運用了神經機制模型的概念加以解釋，同時也闡明了漢字的文字特性導致某些異於拼音文字的認知功能。

關鍵字: 字彙接觸、單字辨認、念字、頻率效果、單字出現頻率、
認字歷程的語音處理、鄰近字頻率效果、形似促發抑制。