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THE COMPARISON OF RELATIVE EFFECTS OF SEMANTIC, HOMOPHONIC AND GRAPHIC PRIMING ON CHINESE CHARACTER RECOGNITION AND NAMING

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Abstract The present study evaluated the effects of homophonic, semantically-related, and graphically-similar primes on character recognition and naming by adopting a within-trials priming procedure and manipulating the character frequency and stimulus onset asynchrony. The experimental results showed that both homophonic and semantically-related primes did not have any priming effect on the processing of high-frequency characters either in recognition or naming task. A facilitation effect of semantic priming was repeatedly observed both in recognition and naming tasks when the target character was of low frequency, while the facilitation effect of homophonic primes was only found in the naming task. An inhibitory effect of graphically-similar primes was also discovered for both tasks. The results confirmed the findings in our previous work [1]. No reliable homophonic priming facilitation effect was obtained in the lexical decision task although character frequency effect and semantic priming effect on the low-frequency character were both vivid. The facilitation effect of homophonic priming can never be greater than that of semantic primes. Our results contradicted the conclusions formed by Perfetti and his colleagues [15, 19, 21].

Key words Lexical access, frequency effect, pre-lexical phonology, priming effect.

1 Introduction

Researchers subscribing to the orthographic depth hypothesis suggested that the word recognition process differs for various orthographies [2-6]. They contended that the pre-lexical analysis of phonology is more suitable for reading shallow orthographies like Serbo-Croatian, whereas deep orthographies like Hebrew or Chinese rely more on a graphically-based direct route to address the mental lexicon. The typical research paradigm evaluates the relative magnitude of the frequency effect and the semantic priming effect on the lexical decision and naming task among different orthographies. The lexical identification process should be involved in a task if semantic priming procedure demonstrates facilitation effect and high frequency words are responded to faster than low frequency words. If the naming task engages lexical identification, lexical identification does not need to engage in the phonology process. Although some evidence supports a direct route in lexical access for shallow languages [7-9], word naming of deep orthographies always engages in lexical identification.

Chinese orthography is a logograph without any stable orthography-to-phonology correspondence. A character can't be pronounced with certainty before it is recognized. For instance, with an identical stem, 也 (pronounced as /ye3/), many characters have various pronunciations, 地 (/di4/), 池 (/chi2/), and 他 (/ta1/). Chinese can show a clear picture of a single direct lexical access route. Some studies of comparing frequency effect on lexical decision and naming [10-11] and further study testing its implication [12] have falsified the affects of pre-lexical phonology on character naming. These results correspond to those from orthographic depth hypothesis-based studies. Also, because there was no regularity effect found in lexical decision task compared to naming which demands pronunciation the authors proposed that the phonology is not obligatory in Chinese character lexical process.

Several researchers still claim that phonological activation is an automatic process that pre-lexically or at-lexically recognized Chinese characters [13-18]. The homophonic priming effect on lexical decision and naming tasks studies, such as [13], demonstrated a significant homophonic priming facilitation effect on the lexical decision task to support the pre-lexical phonology viewpoint of Chinese character recognition. Perfetti with colleagues [15, 19] discovered that homophonic primes, compared to semantic primes, have a greater facilitation effect on the response of naming target characters. They claimed that character identification is automatically and pre-semantically accompanied with phonological activation [17].

Wu and Chen [1] systematically re-evaluated the priming effects of varying prime types on the tasks of lexical decision and naming [1, 20]. According to their results, the homophonic priming effect could not be reliably replicated via the lexical decision task, although semantic priming always facilitates the recognition of low-frequency characters. The homophonic prime could only facilitate the naming of low-frequency characters. This demonstrated a condition of character identification with semantic activation without phonological activation. Moreover, whenever homophonic priming was effective, a semantic priming effect with a greater magnitude was always obtained. These results contradict those of Perfetti and Zhang [15], and Cheng [13], indicating that no convincing evidence exists for the argument that automatic phonology accompanies character recognition. Furthermore, Wu and Chen discovered a substantial inhibition effect from graphic priming either on the lexical decision or naming. Pre-lexical or pre-semantic phonology may not occur through the facilitation effect of homophonic priming because of the inhibition effect of graphic priming and the larger facilitation effect easily obtained by semantic priming. Logically, only with pre-lexical inhibition effect or with larger facilitation effect than that of semantic priming, homophonic priming could be inferred to be a possible evidence of pre-lexical or pre-semantic phonology.

Two experiments each with materials varied and design modified were developed herein to replicate and extend the previous studies.

2 Experiment 1

The priming within trials procedure, in which a prime was presented for a short time and then replaced by a target in a single trial, was adopted to evaluate how target character frequency, stimulus onset asynchrony (SOA), and prime type affect the lexical decision and naming task performance. The target character frequency and prime type were designed within subject variables, while the SOA was between the subjects. If the pre-semantic phonology view could be applied to Chinese character lexical access, then a homophonic priming effect should be observed on the lexical decision task as that on the naming task, and the effect of phonological priming facilitation effect expected should be larger than that of semantic priming [15, 19, 21]. Rather, a deep orthography Chinese with a vivid semantic priming effect on both the naming and lexical decisions, whereas without showing a phonological priming effect during the lexical decision, should otherwise exist because the evidence of direct recognition route exists even in studies of shallow orthographies [7-9].

2.1 Method

2.1.1 *Design and Stimuli*

The subjects were randomly assigned into one of six groups representing combinations of the two between-subjects factors of task (lexical decision vs. naming) and the SOA (50, 350, and 1000 ms). Each group received the same 2 × 2 within-subject factorially arranged materials according to the manipulation of two factors of target character frequency (high vs. low), and prime type (homophonic, graphically similar, semantically related, vs. control). This formed a 2× 3× 2× 4 four-way factorial design.

120 high-frequency characters and 120 low-frequency characters, were each instituted as two parts in the right-left configuration and the target stimulus set were selected from the character database that was computed from a large sample of reading materials (about a million characters in total [22]). The criterion of occurrence frequency was higher than 100 for high-frequency targets (with an average of 380.1) and was below 30 for low-frequency targets (with an average of 7.7). Four characters representing varying types of prime were coupled for each target character. The mean and standard deviations of character frequencies and number of strokes for each prime type are described in Table 1. The Appendix presents a complete list of target characters and the corresponding conditions of prime characters. A pseudo-character was also constructed for each target character as a similar configuration for preparing a pseudo-character target trial.

Table 1 Mean and standard deviations (in parentheses) of frequencies and number strokes of characters for each prime type.

High Freq. Target					Low Freq. Target				
Target	HP	GP	SP	CP	Target	HP	GP	SP	CP
Number of strokes									
11.5	11.8	11.0	10.8	11.4	12.9	11.4	12.5	12.6	13.2
(4.0)	(4.2)	(3.8)	(4.0)	(3.2)	(4.4)	(3.8)	(4.4)	(4.4)	(3.8)
Character frequencies									
380.1	179.7	109.5	536.6	141.3	7.7	248.5	162.5	224.6	92.5
(456.3)	(410.7)	(209.9)	(799.2)	(245.3)	(5.6)	(487.6)	(377.0)	(326.9)	(129.0)

Note: HP = Homophonic Prime, GP = Graphic Prime, SP = Semantic Prime, CP = Control Prime.

Each subject for the naming task received all target characters. The assignment of each target character into the various prime conditions was counter-balanced between subjects. Each target character appeared just once and was preceded by only one of four varying types of prime in a subject. Also, half of the target characters were replaced by the corresponding pseudo-character for the lexical decision task. Twenty additional characters (half of them substituted by pseudo-characters for lexical decision) were also selected for practice trials.

2.1.2 *Apparatus and procedure*

The experiment was controlled by an IBM PC/486 compatible microcomputer. The stimuli were presented using a 15-inch VGA-adapted color monitor that was linked to the microcomputer. A voice-activated circuit linked with a microphone was interfaced to the computer to detect the onset of the subject's pronunciation in the naming task. The reaction times (RTs) and the timing of stimulus display were both measured to the nearest millisecond and synchronized with the video raster. Software was adopted from Wu (1995)[23] to control the experimental procedures and data handling . Each subject was seated approximately 50 cm in front of the video monitor. Subjects received twenty practice trials, each with feedback. Trials that contained an error were repeated until a correct response was made. No feedback was given on the subsequent experimental trials.

The following sequence of events occurred during each trial: (a) An asterisk used as a fixation point was presented at the center of the monitor 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 x 24 dot matrix area, which subtended a visual arc of approximately 0.8 degrees, was presented at the center of the screen for a period of time according to which SOA group the subject was assigned to; (c) The target character was then presented at the same location to replace the prime character. The character remained there until the computer detected the subject's key stroke in the lexical decision task or the subject's pronunciation in the naming task began. The RT timing started from the presentation of the target character until the response was made; (d) The phonetic symbols used in Taiwan to represent the correct pronunciation were then presented above the stimulus character in the naming task. The experimenter seated behind the subject either pressed one of two buttons via a remote connection line to indicate a correct or an incorrect pronunciation of the character (and noted by distinct sounds such as a cough); (e) The whole screen was immediately erased and a 1-s blank was placed before an asterisk accompanied with a warning tone before the next trial was presented.

A modified block randomization strategy was applied on these 240 trials to minimize the possibilities for consecutive trials with the same prime type, the same target frequency, or the same key press (in lexical decision). The shuffling strategy also equalized the appearance of received trials list at any position.

All the trials were evenly and randomly divided into blocks composed of eight trials of various target frequency x prime conditions for naming, and additional eight pseudo-character target trials for lexical decision. An on-line random shuffling assignment procedure was individually performed so that each subject received an idiosyncratic random sequence of block-arranged stimuli.

All subjects were tested individually. Upon arrival, each subject was seated in a sound-proof room and received written instructions on the screen. Both accuracy and speed were emphasized. The subjects were required to take a rest after each consecutive 60 trials and the entire experiment took approximately twenty-five minutes.

2.1.3 *Subjects*

The 157 subjects were fluent readers of Mandarin with normal or corrected-to- normal vision who were recruited from a pool at National Taiwan University. They participated in this experiment to partially fulfill course requirements. They were randomly assigned to six groups according to the manipulation of the Task and SOA factors. Three groups of subjects (40, 37, and 32) received a lexical decision task with 50, 350, or 1000 ms SOA, while the other three groups (each with 25 subjects) received a naming task with each SOA.

2.2 Results and Discussion

Trials with RTs less than 200 ms (indicating prompt responses with possible anticipation) or 2.5 standard deviations more than the mean of the condition to which the trials belonged are treated as outliers when calculating the mean RT of correct responses for each condition within each subject. The re-computed mean correct RTs and mean percentages of errors across subjects under various conditions of target frequency x prime type for each group of particular SOA x task combination are illustrated in Table 2.

Table 2 reveals that naming task took slightly longer than the lexical decision. Furthermore, it also took longer to respond to low-frequency than the high-frequency targets. The statistical significance of these effects was assessed by analyses of variance (ANOVAs) across subjects, $F1$, and across stimulus items, $F2$.

The mean RT data obtained for all subjects in Experiment 1 were submitted to a four-way ANOVA with factors of task (lexical decision, naming), SOA (50, 350, 1000 ms), target character frequency (high, low), and prime type (homophonic, graphically similar, semantically related, unrelated control). The lexical decision was generally slightly faster than naming: $F1(1, 151) = 10.28$, $p < 0.01$, $F2(1, 238) = 24.93$, $p < 0.001$. Many other factors significantly also interacted with the task: task x prime type, $F1(3, 453) = 529.69$, $p < 0.0001$, task x target character frequency, $F1(1, 151) = 9.82$, $p < 0.01$, $F2(1, 238) = 114.75$, $p < 0.0001$, task x prime type x character frequency, $F1(3, 453) = 537.40$, $p < 0.0001$, task x SOA, $F1(2, 151) = 4.60$, $p < 0.05$, $F2(2, 476) = 63.09$, $p < 0.0001$, task x prime type x SOA, $F1(6, 453) = 5.22$, $p < 0.001$, $F2(6, 1428) = 2.34$, $p < 0.05$, task x frequency x SOA, $F1(2, 151) = 5.79$, $p < 0.01$, task x frequency x prime type x SOA, $F1(6, 453) = 6.77$, $p < 0.0001$, $F2(6, 1428) = 3.48$, $p < 0.01$. The higher order interaction effects involved in the task confirm the process is complicated and distinct result patterns will be obtained from various tasks. Two three-way ANOVAs were then separately performed on the RT data for lexical decision and naming.

Table 2 Mean correct latencies in milliseconds as a function of target frequency, prime type,SOA, and task

		High Freq. Target				Low Freq. Target			
Task	SOA	HP	GP	SP	CP	HP	GP	SP	CP
	50 ms	453	522	447	459	588	601	546	640
		(1.2)	(9.2)	(1.5)	(2.5)	(14.3)	(22.3)	(11.2)	(17.8)
LDT	350 ms	441	494	447	457	579	584	560	585
		(2.3)	(5.2)	(1.8)	(2.5)	(9.4)	(13.9)	(8.0)	(15.3)
	1000 ms	479	523	502	494	607	630	591	644
		(0.8)	(3.3)	(0.8)	(1.3)	(8.5)	(8.8)	(5.8)	(13.3)
	50 sm	570	639	573	589	981	1101	886	963
		(6.7)	(8.3)	(7.9)	(7.1)	(20.0)	(25.2)	(20.2)	(26.7)
Naming	350 ms	533	583	521	545	797	832	745	830
		(5.2)	(9.0)	(7.1)	(6.3)	(21.9)	(20.8)	(19.0)	(24.8)
	1000 ms	538	575	536	534	709	761	702	768
		(7.7)	(6.5)	(4.8)	(5.4)	(22.3)	(22.1)	(19.6)	(22.7)

Note: Percentages of errors are given in parentheses. SOA = Stimulus Onset Asynchrony,
HP = Homophonic Prime, GP = Graphic Prime, SP = Semantic Prime, CP = Control Prime.

The three-way ANOVA with target character frequency, prime type, and SOA factors, had the following affect on the lexical decision: the significant sources of variation were target character frequency, $F1(1, 106) = 240.91$, $p < 0.0001$, $F2(1, 238) = 296.50$, $p < 0.0001$, prime type, $F1(3, 318) = 21.93$, $p < 0.001$, $F2(3, 714) = 28.58$, $p < 0.0001$, and target character frequency x prime type, $F1(3, 318) = 12.36$, $p < 0.001$; $F2(3, 714) = 14.34$, $p < 0.0001$. Some other effects were also significant across items: SOA, $F2(2, 476) = 43.59$, $p < 0.0001$, SOA x prime type, $F2(6, 1428) = 2.83$, $p < 0.01$. Further analysis demonstrated that when the target character frequency was high the simple simple main effect of prime type was significant under all SOA conditions: for 50 ms, $F1(3, 636) = 13.07$, $p < 0.0001$, $F2(3, 2142) = 13.82$, $p < 0.0001$, for 350 ms, $F1(3, 636) = 5.71$, $p < 0.01$, $F2(3, 2142) = 7.16$, $p < 0.001$, and for 1000 ms, $F1(3, 636) = 2.91$, $p < 0.05$, $F2(3, 2142) = 4.02$, $p < 0.01$. When the target character frequency was low the simple simple main effect of prime type was significant under all SOA conditions: for 50 ms, $F1(3, 636) = 15.97$, $p < 0.0001$, $F2(3, 2142) = 19.54$, $p < 0.0001$, for 350 ms, $F2(3, 2142) = 2.71$, $p < 0.05$, and for 1000 ms, $F1(3, 636) = 4.71$, $p < 0.01$, $F2(3, 2142) = 5.20$, $p < 0.01$.

The Dunnett method, employed for post hoc comparisons, verified several significant differences between unrelated controls with other primes. The semantically related prime reliably facilitated target processing under all SOA conditions when the target character frequency was low. SOA of 50 ms, 350 ms, and 1000 ms, took 94 ms, 25 ms, and 53 ms less than unrelated control condition to process target character. The homophonic prime also facilitated the target process under some SOA conditions. For 50 or 1000 ms SOA it facilitated RT of 52 ms or 37 ms, respectively. Whereas under 350 ms SOA condition, the homophonic prime was not significantly different with unrelated control. A graphically similar prime facilitated target process took 39 ms. The facilitation effect of homophonic prime did not exceed that of the semantic prime in any SOA condition when the target character frequency was low. On the contrary, a graphically similar prime reliably exerted an inhibitory effect on the lexical decision of target when the target character frequency was high. For 50 ms, 350 ms, and 1000 ms SOA, took 63 ms, 37 ms, and 29 ms more than the unrelated control condition to process the target character. There was no significant effect on target process from semantic and homophonic priming.

The three-way ANOVA with target character frequency, prime type, and SOA factors, had the following affect on the naming process. The significant sources of variation were target character frequency, $F1(1, 45) = 146.93$, $p < 0.0001$, $F2(1, 238) = 292.83$, $p < 0.0001$, prime type, $F1(3, 135) = 16.95$, $p < 0.001$, $F2(3, 714) = 25.79$, $p < 0.0001$, SOA, $F1(2, 45) = 4.89$, $p < 0.05$, $F2(2, 476) = 135.02$, $p < 0.0001$, target character frequency x prime type across items, $F2(3, 714) = 4.32$, $p < 0.01$, SOA x prime type across items, $F2(6, 1428) = 3.43$, $p < 0.01$, and SOA x target character frequency, $F1(2, 45) = 6.63$, $p < 0.01$, $F2(4, 476) = 61.17$, $p < 0.0001$. Further analysis verified that the simple simple main effect of prime type only reach marginal significance across items under SOA conditions of 50 ms and 350 ms: for 50 ms, $F2(3, 2142) = 2.72$, $p < 0.05$, for 350 ms, $F2(3, 2142) = 2.57$, $p < 0.05$, when the target character frequency was high. The simple simple main effect of the prime type was significant under all SOA conditions when the target character frequency was low: for 50 ms, $F1(3, 270) = 15.43$, $p < 0.0001$, $F2(3, 2142) = 27.44$, $p < 0.0001$, for 350 ms, $F1(3, 270) = 3.20$, $p < 0.05$, $F2(3, 2142) = 5.85$, $p < 0.001$, and only across items for 1000 ms, $F2(3, 2142) = 5.04, p < 0.01$.

The Dunnett method demonstrated the following significant differences between unrelated controls with other primes. The semantically related prime reliably facilitated target process under all SOA conditions when the target character frequency was low. SOA of 50 ms, 350 ms, and 1000 ms, took 77 ms, 85 ms, and 66 ms, respectively, less than unrelated control condition to process the target character. The homophonic prime was not significantly different with unrelated control under all SOA conditions. A graphically similar prime inhibited the target process for 138 ms under a 50 ms SOA condition. Similar to the lexical decision, the facilitation effect of homophonic prime also did not exceed that of the semantic prime in any SOA condition when the target character frequency was low. On the contrary, a graphically similar prime reliably exerted an inhibitory effect on the target naming when the target character frequency was high. SOA of 50 ms, 350 ms, and 1000 ms, took 50 ms, 38 ms, and 41 ms more than the unrelated control condition to process the target character. There was no significant effect on target process from semantic and homophonic primes.

The target character frequency was the most effective factor irrespective of task or SOA. There was no semantic or homophonic priming effect while graphic priming exhibited a reliable inhibitory effect, irrespective of task and SOA, when the target character was of high frequency. Significant homophonic priming effect existed on the target lexical decision under some SOA conditions when the target character was of low frequency, whereas only semantic priming had a significant effect under all SOA conditions. The homophonic priming effect never exceeded the semantic priming effect. The observed results contradicted those reported by Perfetti et al. for both lexical decision and naming [15, 19, 21].

3 Experiment 2

Perfetti and Tan [19] manipulated SOA to obtain very 'small' discrepancies among varying levels in a study that employed the naming task to compare the time course of activation among graphic, phonological, and semantic information. However, this method has at least three pitfalls: the inference of lexical access concerning phonology will be inevitably confounded by task because the subjects must pronounce the characters; they did not consider the factor of target character frequency even though it plays the most important role in lexical access. The responses pattern on target characters of high frequency are very distinct from that on low frequency character targets [10, 24, 25]; their manipulation of SOA was practically invalid and might be confounded. The SOA levels were 43, 57, and 85 ms, indicating three, four, or six frame refresh cycles in English text mode for screen display. The refresh time of 14 ms for displaying Chinese characters is not correct. Moreover, the SOA was designed as a between subjects variable. The inference concerned would be inevitably confounded with sampling subject differences among various groups, especially when the discrepancies among varying SOA conditions were indistinguishable.

This experiment adopted the same procedure of priming as in Experiment 1 to simultaneously solve the above-mentioned questions. The manipulated factors were also the same as in Experiment 1, except that SOA was designed as a within subject variable. The levels of SOA were selected as 50, 85, and 120 ms. Which corresponds to 3, 5, and 7 cycles of frame refresh time when displaying Chinese characters in DOS graphic mode.

3.1 Method

3.1.1 Design and Stimuli

Subjects were randomly assigned into one of two groups receiving various tasks (lexical decision vs. naming). Each group of subjects received the same 2 × 2 within-subjects factorially arranged materials according to the manipulation of two target character frequency factors (high vs. low), and prime type (homophonic, graphically similar, semantically related, vs. control). Another within-subjects factor, the SOA (50, 85, vs. 120 ms), was inserted to form a 2×3×2×4 four-way factorial design.

The stimulus materials were the same as in Experiment 1. All target characters for the naming task were received by each subject, while the assignment of each target character into the various prime type and SOA combinations was counter-balanced between subjects. Each target character appeared just once and was preceded by only one of four varying types of prime. With respect to the lexical decision task, an additional 240 trials each with a pseudo character target were constructed and totaled 480 trials. Twenty additional characters (half of them substituted by pseudo-characters for lexical decision) were also selected for practice trials.

3.1.2 *Apparatus and procedure*

The apparatus and procedure were the same as in Experiment 1 except that a more complicated modified block randomization strategy was designed to minimize the possibilities for consecutive trials with the same prime type, target frequency, key press (in lexical decision), or the same SOA. All the trials were evenly and randomly divided into blocks composed of twenty four trials from each target frequency x prime x SOA condition for naming, and an additional twenty four pseudo-character target trials for lexical decision. An on-line random assignment shuffling procedure similar to Experiment 1 was individually performed so that each subject received an idiosyncratic random sequence of block-arranged stimuli.

3.1.3 *Subjects*

The subjects were recruited from the same subject pool as Experiment 1 and were randomly assigned into one of two task groups with 36 subjects each. All subjects were fluent readers of Mandarin with normal or corrected-to-normal vision.

3.2 Results and Discussion

The similar analysis and the exclusion of outliers as that of Experiment 1 were applied. The re-computed mean correct RTs and mean percentages of errors across subjects under various conditions of target frequency x prime type x SOA for each group of task are illustrated in Table 3. Naming took slightly longer than the lexical decision and the low-frequency were slower than the high-frequency target characters both in naming and for the lexical decision. The results confirm the conclusions reached by both previous studies and Experiment 1.

The mean RT data obtained for all subjects in Experiment 2 were submitted to a four-way ANOVA with task (lexical decision, naming), SOA (50, 85, 120 ms), target character frequency (high, low), and prime type (homophonic, graphically similar, semantically related, unrelated control) factors. The lexical decision was slightly faster than naming across items, $F2(1, 238) = 57.31$, $p < 0.0001$. Several other factors also significantly interacted with the task: task x target character frequency, $F1(1, 70) = 11.00, p < 0.001$, $F2(1, 238) = 31.06$, $p < 0.0001$, task x target character frequency x SOA across items, $F2(1, 1428) = 2.13$, $p < 0.05$. The higher order interaction effects involved with the task suggested that the whole picture is complicated since distinct result patterns will be obtained from various tasks. Two three-way ANOVAs were then separately performed on the RT data for naming and the lexical decision.

Table 3 Mean correct latencies in milliseconds as a function of target frequency, prime type, SOA, and task

		High Freq. target				Low Freq. Target			
Task	SOA	HP	GP	SP	CP	HP	GP	SP	CP
	50 ms	452	516	452	464	589	584	552	635
		(1.4)	(8.3)	(3.1)	(4.2)	(10.3)	(8.9)	(7.5)	(13.6)
LDT	85 ms	450	522	458	454	606	594	545	600
		(1.1)	(8.6)	(1.9)	(3.6)	(7.8)	(9.2)	(7.5)	(12.8)
	120 ms	442	504	450	454	578	576	557	615
		(1.4)	(5.8)	(2.2)	(2.5)	(9.2)	(11.9)	(6.1)	(12.2)
	50 ms	470	537	465	469	684	737	696	686
		(1.9)	(6.1)	(2.2)	(5.0)	(16.1)	(24.2)	(17.8)	(21.9)
Naming	85 ms	460	521	474	481	646	703	640	700
		(1.4)	(4.4)	(1.4)	(3.6)	(17.8)	(17.2)	(19.4)	(20.8)
	120 ms	455	524	454	470	666	688	621	697
		(3.9)	(6.7)	(4.4)	(3.9)	(16.9)	(20.8)	(18.1)	(23.6)

Note: Percentages of errors are given in parentheses. SOA = Stimulus Onset Asynchrony, HP = Homophonic Prime, GP = Graphic Prime, SP = Semantic Prime, CP = Control Prime.

The three-way ANOVA with target character frequency, prime type, and SOA factors obtained the following pattern during the lexical decision: the significant sources of variation were the target character frequency, $F1(1, 35) = 167.30$, $p < 0.0001$, $F2(1, 238) = 278.74$, $p<0.0001$, prime type, $F1(3, 105) = 13.96$, $p < 0.0001$, $F2(3, 714) = 13.93$, $p <0.0001$, and target character frequency x prime type, $F1(3, 105) = 18.38$, $p < 0.0001$; $F2(3, 714) = 13.86$, $p<0.0001$. Further analysis demonstrated that the simple simple main effect of prime type was significant under all SOA conditions when the target character frequency was high: for 50 ms, $F1(3, 630) = 5.79$, $p < 0.001$, $F2(3, 2142) = 6.34$, $p < 0.001$, for 85 ms, $F1(3, 630) = 7.37$, $p < 0.001$, $F2(3, 2142) = 8.48$, $p < 0.0001$, and for 120 ms, $F1(3, 630) = 4.99$, $p < 0.01$, $F2(3, 2142) = 4.08$, $p < 0.01$. The simple simple main effect of prime type was significant under all SOA conditions when the target character frequency was low: for 50 ms, $F1(3, 630) = 7.40$, $p < 0.001$, $F2(3, 2142) = 10.37$, $p < 0.0001$, for 85 ms, $F1(3, 630) = 5.00$, $p < 0.01$, $F2(3, 2142) = 4.19$, $p < 0.01$, and for 120 ms, $F1(3, 630) = 3.83$, $p < 0.01$, $F2(3, 2142) = 3.31$, $p < 0.05$.

The Dunnett method for post hoc comparisons verified significant differences existed between unrelated controls with other primes. The semantically related prime reliably facilitated target process under all SOA conditions when the target character frequency was low. SOA of 50 ms, 85 ms, and 120 ms took 83 ms, 55 ms, and 58 ms less than the unrelated control condition to process the target character. The homophonic prime also facilitated the target process under certain SOA conditions. SOA of 50 or 120 ms benefited with ȧn RT of 46 ms, or 37 ms, respectively. Whereas under 85 ms SOA condition, the homophonic prime was not significantly different with unrelated control. The response pattern generated by a graphically similar prime was similar to a homophonic prime. The facilitation effect of a homophonic prime does not exceed that of a semantic prime in any SOA condition when the target character frequency was low. On the contrary, a graphically similar prime exerted a reliably inhibitory effect on the lexical target decision when the target character frequency was high. SOA of 50 ms, 85 ms, and 120 ms took 52 ms, 68 ms, and 50 ms more than the unrelated control condition to process the target character. Semantic and homophonic priming did not have a significant effect on the target processing.

The three-way ANOVA with target character frequency, prime type, and SOA factors displayed the following pattern when performed on naming. The significant sources of variation were the target character frequency, $F1(1, 35) = 77.09$, $p < 0.0001$, $F2(1, 238) = 266.36$, $p<0.0001$, prime type, $F1(3, 105) = 22.51$, $p < 0.0001$, $F2(3, 714) = 9.27$, $p <0.0001$, SOA, $F1(2, 35) = 4.05$, $p < 0.05$, and target character frequency x prime type across items, $F2(3, 714) = 3.42$, $p < 0.05$. Further analysis showed that the simple simple main effect of prime type was significant under all SOA conditions when the target character frequency was high: for 50 ms, $F1(3, 630) = 5.42$, $p < 0.001$, $F2(3, 2142) = 3.50$, $p < 0.001$, for 85 ms, $F1(3, 630) = 3.17$, $p < 0.05$, and for 120 ms, $F1(3, 630) = 4.99$, $p < 0.01$, $F2(3, 2142) = 3.80$, $p < 0.05$. The simple simple main effect of prime type was significant under all SOA conditions when the target character frequency was low: for 50 ms, $F1(3, 630) = 2.78$, $p < 0.05$, for 85 ms, $F1(3, 630) = 5.17$, $p < 0.01$, $F2(3, 2142) = 3.46$, $p < 0.05$, and for 120 ms, $F1(3, 630) = 5.18$, $p < 0.01$, $F2(3, 2142) = 3.78$, $p < 0.05$.

The Dunnett method for post hoc comparisons demonstrated significant differences between unrelated controls with other primes. The semantically related prime reliably facilitated the target processing under certain SOA conditions when the target character frequency was low. SOA of 85 ms and 120 ms took 60 ms and 76 ms less than the unrelated control condition to process the target character. The homophonic prime also facilitated the target process under certain SOA conditions. SOA of 85 and 120 ms took 54 and 31 ms less than the unrelated control condition to process the target character, while SOA of 50 ms was not significantly different with unrelated control. A graphically similar prime inhibited the target process for 51 ms under a 50 ms SOA condition. The facilitation effect of the homophonic prime did not exceed that of the semantic prime in any SOA condition when the target character frequency was low. On the contrary, a graphically similar prime reliably exerted an inhibitory effect on the target naming when the target character frequency was high. SOA of 50 ms, 85 ms, or 120 ms took 68 ms, 40 ms, or 54 ms more than the unrelated control condition to process the target character. Semantic and homophonic priming did not have a significant effect on the target processing.

In sum, the target character frequency was the most effective factor irrespective of task or SOA. When the target character was of high frequency, semantic and homophonic priming did not have a significant effect, whereas graphic priming exhibited a reliable inhibitory effect, irrespective of task or SOA. When the target character was of low frequency, semantic priming did have a significant effect on target lexical decision and naming while 'weak' homophonic priming could be observed only under certain SOA conditions. Homophonic priming was never more significant than semantic priming. The results concur with Experiment 1 and contradict Perfetti et al. [15, 19, 21] for both naming and the lexical decision.

4 Conclusion

The two experiments conducted herein employed a new sample of materials with a larger scope of frequency domain distinct than previous studies [1, 20]. The experiments reached the same conclusions, which contradicted with that of Cheng [13] and some other studies on Chinese character naming by Perfetti and his colleagues [15, 19, 21]. According to their rationale and the evidence provided, the obtained large facilitation effect of homophonic priming on target character recognition was proposed to indicate the role of phonology in lexical access. This did not apply on our studies. Not only a reliable graphic prime inhibitory effect was repeatedly found, implying there existed some possible logic problems in their inference about phonology in character recognition. But also, neither from the primed lexical decision as adopted by Cheng nor from the primed naming by Perfetti et al., the homophonic priming facilitation effect could be reliably replicated as they stated. Thus, phonological activation is not obligatorily engaged pre-lexically or pre-semantically in Chinese character recognition.

It is worth noticing that a reliable graphic priming inhibitory effect upon high frequency target process was repeatedly observed in our studies. It still remains to be explained. Some further studies are now under execution to explore this issue. In an experiment manipulating relative frequency of graphic prime we found that graphic prime with pseudo-character exerts no inhibition on target character recognition. A possible direction of explanation could be proposed like follows. Graphic prime as a real character can quickly activate its semantics and phonology different from that of following target character. Because it exists difficulty in discrimination between these two characters some conflicts might be raised to prolong the target response latencies.

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汉字再认和命名任务中字义、字音、字形启动效应的比较研究

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摘　要　通过运用启动范式和对字频及启动刺激呈现时间的控制，评价了同音启动、语义相关启动和同形启动在汉字识别和命名任务中的效应。在高频字中，同音启动和语义相关启动在命名和识别任务中均不显着，但字形启动的抑制效应在两种任务中均显着；当目标字是低频字时，语义启动效应在识别和命名任务中的各种情况下均显着，而同音启动仅在某些情况中显着。这些结果验证了作者在以前文章中的结论。研究发现，尽管字频效应极为显著，而且语义启动效应在低频字上也存在，但同音启动效应在两种任务上并未被稳定观测到，同音启动的程度在各情况下皆不高于语义启动。该研究的结论与Perfetti等提出的理论有所不同。

关键词　词汇通达，频率效应，词典前语音，启动效应。

Appendix

Characters used in experiment 1 and experiment 2 (with high frequency character target)

Target	Prime Type				Target	Prime Type				Target	Prime Type			
	HP	GP	SP	CP		HP	GP	SP	CP		HP	GP	SP	CP
私	絲	弘	自	訂	許	栩	杵	准	潤	瑞	銳	湍	祥	掩
奶	迺	扔	乳	職	級	輯	圾	層	肝	訴	素	拆	說	棲
初	出	叨	始	肌	刺	次	刷	戳	代	深	申	探	遠	歧
計	紀	什	算	婷	掉	釣	綽	落	暖	眼	演	狠	目	蚊
取	曲	奴	拿	臟	飯	犯	皈	食	診	限	獻	恨	底	仁
即	寂	卻	就	酸	妙	廟	紗	佳	餵	般	頒	股	類	於
院	願	烷	庭	俠	類	淚	頻	區	朗	投	頭	役	丟	艘
減	揀	喊	少	陝	項	像	碩	脖	裕	優	幽	擾	勝	割
睡	稅	唾	眠	雄	煩	帆	頗	躁	則	博	帛	縛	精	傢
迎	螢	仰	來	騷	顧	固	顛	看	赫	校	酵	咬	學	棺
故	僱	改	舊	北	頓	鈍	頑	停	鈣	核	荷	孩	心	碗
攻	宮	玫	打	汁	預	域	頊	先	杭	陽	烊	腸	日	鋸
敗	拜	散	輸	隆	頂	鼎	預	頭	楷	場	昶	湯	地	防
趕	敢	悍	追	帽	牌	排	碑	玩	煌	揚	羊	暢	舉	紡
便	辨	梗	利	測	純	淳	鈍	清	循	路	轆	骼	徑	款
硬	映	哽	剛	喃	找	沼	伐	尋	偶	略	掠	烙	粗	峰
約	曰	灼	契	稀	槍	腔	滄	炮	邦	證	鄭	蹬	明	娟
如	孺	知	像	誌	棒	蚌	捧	桿	鈉	鐘	忠	僮	錶	膀
加	佳	扣	增	誠	鼓	股	肢	脹	紛	險	顯	臉	危	歸
社	射	杜	團	杖	技	繼	吱	藝	謂	隱	蚓	穩	藏	報
好	郝	籽	優	忙	所	鎖	析	址	諾	禮	裡	體	儀	批
封	蜂	討	圍	換	斯	思	斬	此	貓	辭	磁	亂	詞	耗
耐	奈	肘	久	喧	折	輒	祈	斷	偵	鮮	暹	詳	新	班
仙	掀	汕	神	敷	損	筍	隕	失	郭	洋	瘍	群	海	措
紅	洪	扛	赤	韌	旅	履	族	遊	諒	律	氯	津	令	踢
練	戀	揀	習	肚	朋	彭	明	伴	輛	到	稻	致	達	服
孫	飧	係	兒	矽	歌	擱	歐	唱	物	釋	仕	譯	放	件
消	宵	稍	耗	港	飲	引	軟	喝	猶	觀	官	勸	看	汪
娘	孃	浪	媽	渡	師	失	帥	教	俱	權	詮	罐	勢	糕
配	珮	記	匹	偏	婦	復	掃	嫁	棋	快	檜	決	速	棵
流	榴	梳	通	拜	秋	蚯	伙	涼	版	獨	牘	濁	孤	牧
階	揭	楷	梯	概	借	界	惜	貸	扶	擔	丹	瞻	挑	邸
親	侵	硯	近	衫	鎮	震	滇	鄉	須	除	雛	徐	去	慌
現	縣	視	露	海	靜	勁	睜	寂	額	脫	托	銳	卸	磁
徒	途	陡	空	球	終	忠	咚	末	脾	晚	碗	浼	遲	猿
連	簾	陣	接	討	塊	劊	魂	團	淑	語	宇	悟	言	訊
野	冶	舒	荒	提	功	公	巧	效	部	船	傳	鉛	舶	凱
理	禮	埋	道	竭	唯	違	准	僅	修	講	蔣	溝	述	值
玩	丸	阮	嬉	挨	精	經	猜	巧	嫌	驗	燕	撿	查	腔
松	嵩	蚣	柏	誘	法	髮	怯	規	嫂	保	飽	娛	護	隸

Note: HP = Homophonic Prime, GP = Graphemic Prime,
SP = Semantic Prime, CP = Control Prime.

Appendix

Characters used in experiment 1 and experiment 2 (with low frequency character target)

Target	Prime Type				Target	Prime Type				Target	Prime Type			
	HP	GP	SP	CP		HP	GP	SP	CP		HP	GP	SP	CP
沐	牧	休	浴	睹	旌	競	旋	旗	碟	穫	貨	護	收	襪
蜒	沿	誕	彎	餚	倏	漱	條	快	副	咽	業	姻	喉	償
胝	織	抵	胼	冷	垠	淫	很	邊	狗	畦	曦	鮭	田	拓
坎	檻	吹	坷	齡	靼	達	袒	番	映	蛙	挖	桂	蝌	酥
祉	紙	扯	福	統	沫	漠	味	泡	妮	侈	恥	移	奢	備
耿	哽	狄	直	珊	褶	輒	熠	疊	距	橙	城	瞪	橘	戰
隘	愛	溢	狹	楨	懦	諾	儒	懼	捷	憧	充	瞳	影	僑
腊	辣	醋	醃	陞	儕	豺	擠	輩	鍋	粥	周	弼	飯	鄰
惕	悌	賜	警	瑪	呱	挖	孤	哭	綠	鑲	箱	釀	嵌	郊
耽	單	枕	遲	搞	鉗	錢	柑	夾	佈	恃	逝	待	靠	跡
吠	肺	伏	叫	融	佃	電	細	租	彿	峙	制	特	對	恍
咀	矩	姐	嚼	捨	釉	誘	迪	彩	秘	橡	向	豫	膠	曉
棟	洞	陳	柱	採	歿	墨	段	滅	糟	瀆	愧	遺	退	鄭
踝	淮	課	腳	睬	漬	字	積	髒	驟	賄	會	侑	錢	操
餤	堰	談	火	帳	嘖	澤	債	奇	嶼	孅	先	懺	細	爐
蛀	助	往	蝕	勒	鑠	朔	礫	亮	濱	栩	許	翎	真	瞞
咋	柵	昨	驚	泡	紳	身	坤	尊	跟	弭	米	洱	消	曦
貶	扁	泛	低	畔	珀	破	拍	琥	政	饞	蟬	纔	吃	翰
猙	楨	淨	醜	務	睦	牧	陸	和	犯	袂	媚	訣	袖	眺
堵	篤	緒	塞	驅	覬	寄	凱	窺	標	恬	闐	括	靜	拱
絀	觸	咄	廢	幔	憚	但	禪	怕	際	騁	逞	聘	跑	例
朕	振	送	尊	雖	蟬	潺	彈	鳴	擱	鐲	啄	觸	環	刊
餽	潰	醜	送	稚	犢	獨	續	牛	濟	贍	扇	膽	養	洶
椎	追	維	刺	帖	贖	叔	讀	買	僵	棧	佔	殘	住	復
帷	微	雜	幕	胡	謫	哲	滴	逐	瀋	蛻	退	說	變	譜
倩	歉	清	美	啄	羶	衫	壇	腥	弧	殮	鏈	儉	棺	緝
粘	年	站	貼	執	僥	餃	燒	倖	姓	蠅	營	繩	蚊	銘
飴	姨	胎	樂	縷	驍	梟	饒	勇	佣	竣	菌	梭	畢	瞧
殆	代	怡	危	演	饌	賺	選	餚	袖	肋	垃	幼	骨	潘
駒	居	鉤	馬	檸	噱	薛	據	驚	礦	叱	赤	牝	罵	潦
齣	出	夠	戲	擦	詮	泉	栓	釋	濾	諭	域	偷	令	哈
襤	攔	鑑	破	佑	划	滑	列	搖	敵	悖	輩	脖	逆	詬
檻	侃	艦	門	飼	穗	歲	總	麥	伸	弛	匙	她	鬆	澄
蝠	浮	逼	蝙	糾	撕	司	撒	裂	障	訖	泣	屹	終	潑
泅	球	泗	涉	駛	戟	脊	幹	槍	境	悚	聳	辣	懼	臨
佚	抑	秩	遺	尉	揖	依	輯	禮	漁	豹	報	酌	獅	榻
沱	馱	蛇	滂	磚	詭	軌	脆	詐	滷	灶	造	牡	爐	胰
啜	綽	綴	哭	慷	恪	剋	絡	守	稷	侮	午	梅	辱	瓶
濯	拙	耀	洗	膝	餉	想	晌	薪	擺	蛹	永	桶	雛	餅
秤	稱	坪	量	疑	幡	翻	播	旗	膠	虹	鴻	缸	彩	墳

Note: HP = Homophonic Prime, GP = Graphemic Prime,
SP = Semantic Prime, CP = Control Prime.