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PHONOLOGY AND ACCESS TO CHINESE CHARACTER MEANING[1, 2]

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Summary.—One of the central concerns in theories of reading skills is the role of phonology in access to word meaning. The present study focused on this issue in Chinese to examine the extent to which phonology affects Chinese character recognition. Two naming experiments were conducted with a phonologically mediated semantic priming paradigm, and the relative frequencies of semantic associates of the targets and their homophones were manipulated systematically. Analyses showed that a semantic associate produced robust priming on target naming at 57- and 250-msec. stimulus onset asynchronies, but only the low frequency homophones of high frequency semantic associates facilitated target naming at a 250-msec. stimulus onset asynchrony. These results indicate the role of phonology is neither obligatory nor efficient in access to Chinese character meaning, contradicting the key assumptions of the lexical constituency model. A revised parallel access model that emphasizes visual access to semantics is suggested as a more plausible account.

The role of phonology in semantic access is a central issue in reading research and has been extensively studied over the past three decades (e.g., Coltheart, 1978; Van Orden, 1987; Rayner & Pollatsek, 1989; Lesch & Pollatsek, 1993; Frost, 1998; Harm & Seidenberg, 2004; Rastle & Brysbaert, 2006). Studies of alphabetical scripts have suggested three views on this issue. While the direct access view proposed that access to a character's meaning is directly from its orthographic representations with no reference to its phonology (e.g., Baron, 1973), the phonological mediation hypothesis (e.g., Van Orden, 1987) claimed that orthography first activates pre-lexical phonology which then activates representation of meanings. As a compromise between the two, the dual-route view posited parallel access via both the direct and the mediated routes and a more dominant role of the former in skilled reading or for high frequency character processing (e.g., Coltheart, 1978, 2005).

The Chinese script is considered a logographic writing system with-

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out orthography-to-phonology correspondences, excluding the possibility of prelexical phonology. The basic writing unit, a character, corresponds to a morpheme in Chinese. These unique characteristics led to a traditional view that meaning access for Chinese characters goes by the direct route and bypasses phonology (e.g., Baron, 1973; Hoosain, 1991). From the 1990s, this view has been challenged by more and more studies demonstrating the involvement of phonology in access to Chinese character meaning (e.g., Leck, Weekes, & Chen, 1995; Perfetti & Zhang, 1995; Tan & Perfetti, 1997; Chua, 1999; Xu, Pollatsek, & Potter, 1999; Zhou & Marslen-Wilson, 1999). All these studies revealed that the meaning of a Chinese character can be accessed through its orthographic information and/or phonological information. However, to what extent phonology plays a role in access to meaning of Chinese characters is still disputed.

Perfetti and colleagues argued for a strong role of phonology in Chinese character meaning activation (e.g., Perfetti & Zhang, 1995; Tan & Perfetti, 1997; Perfetti & Tan, 1998; Liu, Perfetti, & Hart, 2003; Perfetti, Liu, & Tan, 2005). In a series of studies with different paradigms, they found that phonology was routinely activated earlier than semantic information (e.g., Tan, Hoosain, & Peng, 1995; Perfetti & Zhang, 1995; Perfetti & Tan, 1998; Liu, *et al*., 2003). These findings indicated that phonology would play an important role in activating character meaning. Tan and Perfetti (1997) further found that phonological information provided an early constraint on meaning activation of Chinese characters, using a phonologically mediated semantic priming paradigm. They showed that naming a target character was primed by its synonym (i.e., semantic priming) and also by homophones of the synonym (referred to as phonologically mediated semantic priming) when the synonym had a small number of homophones. When the synonym had a large number of homophones, the synonym priming was reduced, and the phonologically mediated priming disappeared. These results imply that phonology provides a strong constraint on the semantic access in Chinese, even though meaning can be accessed via the direct route based on orthography.

Perfetti and colleagues argued that this role of phonology is not fully accounted for by the phonological mediation emphasizing the necessity of phonology in meaning activation. Alternatively, they suggested that phonology may not mediate but rather "negotiate" with the orthographic information to activate character meanings. Even if phonology does not directly cause access to character meaning (e.g., in the case of a large number of homophones), it can still stabilize character identity. Based on these studies, they proposed a lexical constituent model claiming that semantic access involves phonological activation that occurs rapidly and obligatorily during character identification, and due to its earlier activation than semantics, phonology always provides strong constraints on meaning activation (Perfetti, *et al*., 2005).

There are two major problems with this model. One is that their central findings were not replicated by others using the same materials and paradigm (Zhou & Marslen-Wilson, 1999, 2000; Chen & Shu, 2001). The other is that it contradicts with some recent studies showing that patients suffering from phonological deficits due to lesions had intact understanding of the meaning of printed characters (e.g., Bi, Han, & Zhang, 2009; Han & Bi, 2009).

There are other studies supporting the involvement of phonology, although in ways different from what was proposed by the lexical constituent model (Chua, 1999; Xu, *et al*., 1999). Xu, *et al*. (1999) showed that both irrelevant phonological and orthographic similarities interfered with semantic judgment, supporting a parallel access hypothesis where the indirect route via mediation and the direct route based on orthography operate in a horse-race fashion. Although their results were similar for low and high frequency characters, they considered these results tentative, noting the *post hoc* nature of their analysis and admitting the under-specification of their model carrying too much explanatory power. They therefore suggested the inclusion of character frequency explicitly in future studies to see whether frequency affects the relative strength of the two routes.

Leck, *et al.* (1995) showed that phonologically similar foils interfered with semantic categorization only when they were also visually similar to the target, but visually similar foils interfered with semantic categorization regardless of phonological similarity. Different from the above two models, they suggested that the direct access route plays a more dominant role in meaning access compared with the mediated route (see also Zhou & Marslen-Wilson, 1999).

The above review shows that a dual-route framework is generally considered suitable to explain the role of phonology in access to Chinese character meaning. However, there are still disputes across different models in terms of the specific role of phonology in this framework. One possibility is that character frequency may be a critical determinant and discrepancies in theoretical standpoints may originate from incomplete sampling of the full frequency range. For example, the lexical constituent model is mainly based on studies using high frequency characters (e.g., Tan & Perfetti, 1997; Perfetti & Tan, 1998). Studies that did include both high and low frequency characters did not manipulate character frequency systematically (e.g., Xu, *et al*., 1999; Zhou & Marslen-Wilson, 1999).

A recent study of event-related potentials found earlier phonological activation compared with semantic activation for low frequency characters but the opposite pattern for high frequency characters (Zhang, Zhang,

& Kong, 2009). The results were difficult to explain with either the lexical constituent model—in which a rigid sequence of phonology and semantics activation would be expected independent of frequency—or the parallel access hypothesis, which lacks specific details for concrete predictions. However, the homophone judgment task and the semantic relatedness judgment task used in that event-related potentials study would only inform about the time course of lexical activation. Results from such tasks only allow indirect inferences about phonological involvement in meaning access (e.g., Zhou & Marslen-Wilson, 1999).

As a follow-up, the present study used a phonologically mediated semantic-priming paradigm, which is a well-accepted paradigm, to directly address the role of phonology (e.g., Lesch & Pollatsek, 1993). In addition to frequency manipulation, two stimulus onset asynchronies, 57 msec. and 250 msec., were included for better comparison with the literature (e.g., Tan & Perfetti, 1997; Zhou & Marslen-Wilson, 1999). It was expected that mediated phonological priming would be observed, as has been repeatedly demonstrated before. Such a priming effect may be confined to low frequency characters. This is based on the above results from event-related potential studies, i.e., that phonological activation occurred earlier than semantic activation only for low frequency characters. It was also expected that the priming effect would be more likely to occur at long stimulus onset asynchrony, same as in previous studies (e.g., Tan & Perfetti, 1997; Zhou & Marslen-Wilson, 1999). Finally, using visually dissimilar prime and target pairs, it was possible to see if phonological effects are contingent on orthographic similarity.

EXPERIMENT 1

Method

Participants

Fifty undergraduates (23 men) from South China Normal University (Guangzhou, China) participated and were paid for their participation. All were right-handed, native Mandarin Chinese speakers who reported normal or corrected-to-normal vision. Informed consent was obtained following approval of the research protocol by the institutional review board. Handedness was measured based on participants' responses to the Edinburgh Handedness Inventory (• • •, 19XX).

Materials

All character stimuli were chosen from the Modern Chinese Frequency Dictionary (*Xiandai Hanyu Pinlu Cidian*, 1986), consisting of a total of 120 target characters, each associated with five different prime characters making five experimental conditions.

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As shown in Table 1, in the High/Semantic condition, the target was a high frequency character and semantically related to the prime (synonyms, antonyms, or category coordinates of the target), i.e., “年” and “岁.” For easy reference, the prime in this condition (i.e., “岁”) is referred to as the semantic associate of the target (e.g., “年). For all items, a target and its semantic associate were different from each other in phonology. In the High Homophony and the Low Homophony conditions, the primes (i.e., “碎” and “祟”) of high and low character frequency, respectively, were homophonic to “岁,” the semantic associate of their corresponding target. These homophone pairs were the same in both pronunciation and tone but dissimilar in orthography, with less than 5% of the pairs sharing a common phonetic or semantic radical (10 in the total 240 pairs). The High Control condition served as control for the High Homophony condition by re-pairing the prime-target pairs in the latter condition to form prime-target pairs unrelated semantically or phonologically, or orthographically. The two conditions then involved the same set of primes and the same mean frequency values. Similarly, the Low Control condition was the control for the Low Homophony condition. The mean frequency was matched among the three kinds of high frequency primes and the two kinds of low frequency primes, as is shown in Table 1. In addition, 20 undergraduates evaluated the extent of semantic relatedness between the targets and the semantic associates on a 7-point scale with 1 for lowest and 7 for highest relationship. The average rating scores were 6.21 for the high frequency pairs and 6.09 for the low frequency pairs, with no significant difference between the two (item analysis, $t_{59} = 1.64$, $p > .1$).

All the prime-target pairs were counterbalanced using a Latin square design and split into five test versions. Each version included 120 prime-target pairs presented in pseudorandom order. In each version, no prime or target was repeated. Each participant only attended one version, so, although each participant viewed all five kinds of prime-target pairs in one version, they would see the same prime or target once.

Procedure

Participants were seated about 50 cm away from a computer screen in a quiet room. All character stimuli were in 28-point Songti font, presented at the center of the screen in white color against a black background. The size of each character was about 2 cm × 2 cm in size. The software DMDX (Forster & Forster, 2003) was used to control stimulus presentation and to record naming response times. Each trial started with a fixation cross presented for 1,000 msec., followed by a prime for 57 msec. The target character was then shown and disappeared either upon response or after 2,000 msec. without a response. The next trial started 2,000 msec. after the target

TABLE 1

STIMULUS CHARACTERISTICS FOR DIFFERENT CONDITIONS IN EXPS. 1 AND 2

	Prime Type					
	High/ Semantic	High Homophony	High Control	Low Homophony	Low Control	Target
Character	岁	碎	负	祟	驸	年
Pinyin	/sui4/	/sui4/	/fu4/	/sui4/	/fu4/	/nian2/
Meaning	Year	Broken	Bear	Evil spirit	Side horse	Year
Stroke	8	9	9	10	10	8
Frequency	1,338	554	554	4	4	1,203
	Low/ Semantic	High Homophony	High Control	Low Homophony	Low Control	Target
Character	觅	蜜	灵	幂	绫	寻
Pinyin	/mi4/	/mi4/	/ling2/	/mi4/	/ling2/	/xun2/
Meaning	Look for	Honey	Clever	Power	Damask silk	Seek
Stroke	10	10	10	11	11	9
Frequency	4	127	127	4	4	490

Note.—In the top panel, the semantic associate of the target is of high frequency and its high frequency and low frequency homophones were used in the two homophone conditions, each with a frequency-matched control condition. The bottom panel is the same except that the semantic associate of the target is of low frequency. Mean stroke number and frequency values are listed for each condition. High/Semantic: high frequency semantic associate of the target; Low/Semantic: low frequency semantic associate of the target; High Homophony: high frequency homophone of the semantic associate; High Control: frequency-matched control for the High Homophony condition; Low Homophony: low frequency homophones of the semantic associate; and Low Control: frequency matched control for the Low Homophony condition. One sample character is used for each condition for illustration purposes. Stroke numbers and frequency show mean stroke number and frequency for all characters in each condition.

offset. Participants were asked to view both the prime and the target but to name only the targets as quickly and accurately as possible. Naming latencies were measured from target onset to when a voice key was triggered. An experimenter sat beside the participant to record their naming accuracies. Each participant had 15 practice trials before the actual test.

RESULTS

Trials with naming latencies less than 300 msec. or more than 1,500 msec. or with no response within the 2,000 msec. time window were excluded from analysis. They accounted for less than 2% of the total data. The mean naming response times (RTs) and error rates are shown in Table 2. One-way analysis of variance on error rates did not yield any effect of condition ($Fs < 1.00$).

In the present experimental design, a semantic associate shared the same control primes with a group of homophones of the semantic associates. That is, they had the same baseline. Thus, the present design was not a standard design with factors and their levels balanced (e.g., seman-

Author: Should these be "Homophones" instead?

TABLE 2

Means and Standard Deviations For Naming Latencies and Error Rates in Exp. 1

	Prime Type									
	High/ Semantic		High Homophony		High Control		Low Homophony		Low Control	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
RT (msec.)	600	59	612	52	620	67	617	63	620	79
Error, %	1.2	3.2	0.8	2.8	1.3	4.7	1.3	5.4	1.0	4.0
	Low/ Semantic		High Homophony		High Control		Low Homophony		Low Control	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
RT (msec.)	623	51	635	75	631	46	642	67	638	46
Error, %	1.7	4.6	1.0	4.0	0.5	2.2	2.0	5.8	2.2	6.9

Note.—High/Semantic: high frequency semantic associate of the target; Low/Semantic: low frequency semantic associate of the target; High Homophony: high frequency homophone of the semantic associate; High Control: frequency-matched control for the High Homophony condition; Low Homophony: low frequency homophones of the semantic associate; and Low Control: frequency matched control for the Low Homophony condition.

tic associate and their homophones had different baselines). Two analyses of variance were conducted to examine the effect of different primes and character frequency. *F* ratios were reported by participants (*F1*) and items (*F2*). The partial eta squared calculated using SPSS with an alpha level of .05 was provided as effect size. The same procedure was used in Exp. 2.

In the first analysis of variance, there were two within-participant factors to be analyzed. One was the frequency of the primes (high and low frequency). The other was the types of primes: the semantic associate of the target, the homophone of semantic associate, and their controls. In this analysis, the three types of primes had the same high or low frequencies. The purpose of the first overall analysis of variance was to examine the effect of the semantic associates and their homophones with similar frequencies.

The first analysis of variance showed that there was a significant main effect of prime frequency both by participants ($F1_{1,49} = 25.92$, $MSE = 1{,}750.49$; $\eta^2_p = 0.35$, $p < .001$) and by items ($F2_{1,59} = 10.15$, $MSE = 5{,}158.05$; $\eta^2_p = 0.15$, $p < .005$), indicating that responses to targets were faster when the primes were high frequency characters. The main effect of prime type was also significant both by participants ($F1_{2,98} = 6.99$, $MSE = 984.04$; $\eta^2_p = 0.13$, $p < .005$) and by items ($F2_{2,118} = 3.98$, $MSE = 2{,}720.21$; $\eta^2_p = 0.06$, $p < .05$). Pairwise comparisons showed that naming time in the semantic associate condition (612 msec.) was significantly shorter than that in the homophone condition (627 msec.) and the control condition (629 msec., *p*s < .05), but there was no difference between the homophone and the control conditions ($p > .05$).

In the second analysis of variance, only the homophones of the semantic associates and their corresponding controls were included as variables. There were thus three within-participant factors to be analyzed, prime frequency (high frequency versus low frequency), type of relation between primes and targets (primed versus control), and the frequency of semantic associates that the homophones of semantic associates corresponded to (high frequency versus low frequency, here referred to as *frequency match* to be convenient). The purpose of the second overall analysis of variance was to examine whether the priming effect of the homophones of semantic associates was affected by frequency of the homophones.

The second analysis of variance showed that there was a significant main effect of frequency match both by participants ($F1_{1,49} = 18.74$, $MSE = 2{,}349.22$; $\eta^2_p = 0.28$, $p < .001$) and by items ($F2_{1,59} = 5.36$, $MSE = 8{,}677.25$; $\eta^2_p = 0.08$, $p < .05$), indicating that responses to targets were faster if they were preceded by homophones of the high frequency semantic associates of the targets than by homophones of the low frequency semantic associates. There were no other significant main or interaction effects.

Discussion

Analyses showed that only the semantic associate of the targets facilitated the naming of the targets regardless of their frequency. Neither the high nor low character frequency homophones of the semantic associates produced a significant priming effect relative to their controls. Such a finding repeats the null findings of phonologically mediated semantic priming with a short stimulus onset asynchrony on the same task in which semantic associates and their homophones were visually dissimilar (e.g., Zhou, Shu, Bi, & Shi, 1999). One interpretation is that the results support the direct access hypothesis with no phonological mediation in access to meaning.

Alternatively, it may also be difficult to observe phonological priming with short stimulus onset asynchrony. In written Chinese, there are abundant homophones, which imply that one phonological unit is possibly associated with many different semantic units. For example, according to the *Xiandai Hanyu Cidian* [*Modern Chinese Dictionary*] (1992), there are 76 homophones associated with the pronunciation /xi1/ [e.g., 西(west), 息(rest), 昔(previous), ...], and 121 characters with the pronunciation /xi/ (disregarding the same tones). These 76 homophones have about 100 meanings listed in this dictionary. Cases like this are very common in Chinese. Therefore, even if the phonology of the prime character is activated rapidly, it may be inefficient and slow to use this information to activate the meanings of its many homophones, failing to produce any phonologically mediated semantic priming on the target. That is, with a longer stimulus onset asynchrony, there may be enough time for phonology to activate the meanings of the homophones and to prime the target semantically related to a specific homophone.

One problem with this experiment was that the target frequency was not matched across the low and high character frequency conditions, being 1,203 times per million for the former and 490 times per million for the latter. This difference may have confounded the manipulation of the prime frequency. To examine this possibility, nine target characters with the highest frequencies in the high frequency condition were removed so that the remaining 51 target characters would have a mean character frequency of 488 times per million, comparable to the 490 times per million of all the target characters in the low character frequency condition. The RTs for the five experimental conditions were essentially the same before and after deleting these outlier characters (High/Semantic: 596 vs 600 msec.; High Homophony: 613 versus 612 msec.; High Control: 623 versus 620 msec.; Low Homophony: 625 versus 617 msec.; Low Control: 623 versus 620 msec.). Briefly, the frequency match effects observed could not be attributed to the less-than-optimal control over target character frequencies.

EXPERIMENT 2

In this experiment, the first experiment was repeated at a longer stimulus onset asynchrony (250 msec.) to see whether a different pattern of phonologic priming would be observed. The 250-msec. stimulus onset asynchrony lies in the range generally accepted as tapping automatic priming rather than using conscious guessing strategies (e.g., Neely, 1977; Lesch & Pollatsek, 1993).

Method

Participants

A new group of 50 undergraduates (26 men) from Hebei University participated in this experiment. All participants were right-handed, native Mandarin Chinese speakers, who reported normal or corrected-to-normal vision. Informed consent was obtained following an IRB-approved research protocol. Handedness was assessed as in Exp. 1.

Materials and Procedure

The materials and procedure were the same as those used in Exp.1 except the primes were presented at 250 msec. instead of 57 msec.

Results

Exclusion of data followed the same procedure as in Exp. 1 and less than 1% of the total data were discarded. All analyses of Exp. 2 were identical to those in Exp. 1. Mean RTs and error rates are shown in Table 3. One-way analysis of variance on error rates did not yield any effect of condition ($Fs < 1.00$).

TABLE 3

MEANS AND STANDARD DEVIATIONS FOR NAMING LATENCIES AND ERROR RATES IN EXP. 2

	Prime Type									
	High/ Semantic		High Homophony		High Control		Low Homophony		Low Control	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
RT (msec.)	616	61	634	72	630	58	628	61	643	74
Error, %	1.0	4.8	0.7	3.1	0.8	3.8	2.0	6.3	1.0	3.5
	Low/ Semantic		High Homophony		High Control		Low Homophony		Low Control	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
RT (msec.)	637	48	652	55	645	62	655	60	655	60
Error, %	1.0	3.5	1.7	4.9	0.7	4.1	1.5	5.2	0.8	3.8

Note.—High/Semantic: high frequency semantic associate of the target; Low/Semantic: low frequency semantic associate of the target; High Homophony: high frequency homophone of the semantic associate; High Control: frequency-matched control for the High Homophony condition; Low Homophony: low frequency homophones of the semantic associate; and Low Control: frequency matched control for the Low Homophony condition.

In the first analysis of variance, there were two within-participant factors to be analyzed, the frequencies of the primes (high and low character frequency) and the types of primes: the semantic associate of the target, the homophone of semantic associate, and their controls. In this analysis of variance, the three types of primes had the same high or low character frequencies. The purpose of the first overall analysis of variance was to examine the effect of the semantic associate and their homophones with similar character frequencies.

The first analysis of variance gave a significant main effect for prime frequency both by participants ($F1_{1,49} = 19.32$, $MSE = 2{,}196.03$; $\eta^2_p = 0.28$, $p < .001$) and by items ($F2_{1,59} = 7.34$, $MSE = 5{,}969.47$; $\eta^2_p = 0.11$, $p < .01$), indicating that responses to targets were faster when the primes were high frequency characters. The main effect of prime type was also significant both by participants ($F1_{2,98} = 7.28$, $MSE = 1{,}155.43$; $\eta^2_p = 0.13$, $p < .01$) and by items ($F2_{2,118} = 7.35$, $MSE = 1{,}580.09$; $\eta^2_p = 0.11$, $p < .001$). Pairwise comparison showed that naming time in the semantic condition (626 msec.) was significantly shorter than that in the homophone condition (642 msec.) and in the control condition (642 msec.; ps $< .005$), but there was no difference between the homophonic primes and the controls ($p > 0.1$).

As in Exp. 1, the second analysis of variance involved three within-participant factors, i.e., prime frequency, relation type, and character frequency match, to examine if the phonological priming effect from homophones was influenced by the frequencies of homophones and semantic primes. The results showed that there was significant main effect of character frequency match both by participants ($F1_{1,49} = 18.82$, $MSE = 2{,}257.44$; $\eta^2_p = 0.28$,

$p < .001$) and by items ($F2_{1,59} = 5.09$, $MSE = 7{,}761.70$; $\eta^2_p = 0.08$, $p < .05$), indicating that responses to targets were faster if they were preceded by homophones of the high frequency semantic associates of the targets. The two-way interaction between prime frequency and relation type was significant by participants ($F1_{1,49} = 7.15$, $MSE = 722.47$; $\eta^2_p = 0.13$, $p < .05$) and by items ($F2_{1,59} = 4.07$, $MSE = 1256.38$, $\eta^2_p = 0.07$, $p < .05$). Pairwise comparisons showed that low frequency homophones of the semantic associates of the targets significantly facilitated target naming by participants ($F1_{1,49} = 5.73$, $\eta^2_p = 0.11$, $p < .05$) but not by items ($F2_{1,59} = 1.76$, $p = .19$), but there was no such facilitation for the high character frequency homophones ($Fs < 1.00$). There was no other significant main or interaction effect, including the three-way interaction ($Fs < 1.00$). Note that analysis focusing on the low frequency homophones revealed a marginally significant two-way interaction between frequency and relation type by participants ($F1_{1,49} = 12.89$, $MSE = 906.33$; $\eta^2_p = 0.05$, $p = .12$) and by items ($F2_{1,59} = 2.23$, $MSE = 1{,}478.42$; $\eta^2_p = 0.04$, $p = .14$). Analysis focusing on the high frequency homophones did not reveal such a trend ($Fs < 1.00$). Possibly with increased statistical power, the differential pattern of results between these two two-way interactions would yield a significant three-way interaction.

Discussion

These results supported a dual-route access view in accessing Chinese character meaning. That is, both direct access and phonologically mediated access exist in access to character meaning, but the mediated access seems to be slow and not essential. These results were consistent with the expectation that phonological priming might be shown only on the low character frequency homophones of the semantic associates in long stimulus onset asynchrony setting, based on unique properties of the Chinese writing system as described in the discussion of Experiment 1. On the other hand, phonology was also activated for high frequency characters except with a slower speed and not mediating semantic access. The activated phonological information may serve an additional function to maintain information in working memory during the whole character recognition.

A similar analysis was performed as in Exp. 1 excluding the nine target characters of the highest frequency for the high frequency prime condition and confirmed that the significant main effect of frequency match could not be attributed to the less-than-optimal control over target character frequencies.

GENERAL DISCUSSION

With a systematic manipulation of frequencies of semantic associates of the targets and their homophones, in two character-naming experiments using the phonologically mediated semantic-priming paradigm to examine the role of phonology in accessing Chinese character-meaning, robust facilitation of target naming from semantic associates, but no priming from homophones of a semantic associate other than the low frequency homophones of the high frequency semantic associates at 250 msec. stimulus onset asynchrony were found.

The phonologically mediated semantic priming at a long stimulus onset asynchrony in the present experiment was not consistent with the assumptions of the direct access view that character meaning is accessed through a direct orthography-semantic link, bypassing phonological activation. Was this the case, one should not observe any phonologically mediated priming from the homophones of the semantic associates of the targets in the present two experiments. Current findings also seem to imply that phonologically mediated priming from the homophones did not depend on the visual similarity of Chinese characters because there was no visual similarity between semantic associates and their homophones.

The results suggest two routes in access to Chinese character meaning in connection with the dual route framework in Chinese. However, these findings further suggest phonology may not be obligatory for semantic access and the phonological route may be too slow and inefficient in semantic access (even if phonological activation is automatic or early). These findings were consistent with many previous findings suggesting that the role of phonology in semantic access is influenced by character frequency and may be more important for low frequency characters than high frequency characters (e.g., Coltheart, 1978, 2005; Davelar, Coltheart, Besner, & Jonasson, 1978; Seidenberg, 1985; Jared & Seidenberg, 1991; Coltheart, Patterson, & Leahy, 1994), but not with others such as Luo (1996) and Folk (1999) claiming a dual-route access and emphasizing the primacy of phonology in lexical access. Similarly, the present findings do not support the lexical constituent model for Chinese character recognition which holds essentially the same view as the Luo (1996) and Folk (1999) models. If phonology was activated early and required to access lexical semantics in Chinese, as suggested by the lexical constituent model, significant priming from both high and low frequency homophones of the semantic associates of the targets should be observed in all stimulus onset asynchrony conditions of the experiments. But, although the findings were inconsistent with a general prediction, the lexical constituency model posits that phonological activation should be faster than semantic activation; a formal computer simulation is needed to see if the model really fails to capture the present pattern of results.

These findings give a better specification of the parallel access hypothesis model in which lexical semantics are accessed along two routes in parallel and phonological activation plays equally important role in access to meaning of both high and low frequency Chinese characters. Current findings indicate, relative to the direct route, the mediated route may be secondary or not essential and its access speed is also slower in parallel access to character meaning. These findings therefore constrain the parallel access hypothesis model by specifying the relative strength of two routes in this model, suggesting a more dominant direct access route. That the two access routes may not be used equally in semantic access of Chinese characters suggests a revision of the parallel access model.

Regarding the phonologically mediated route, use of a variant of the dual route models may be relevant to strategic process or depend on the contextual or task demands (e.g., Carr, Davidson, & Hawkins, 1978; Coltheart, 1978; Davelar, *et al*., 1978; Pugh, Rexer, & Katz, 1994). For instance, long stimulus onset asynchronies may allow enough time for participants to use strategies intentionally. In addition, some previous Chinese research reported significant priming from homophones of semantic associates only when homophones were regular characters or shared phonetic radicals with semantic associates in phonologically mediated semantic priming tasks (e.g., Zhou & Marslen-Wilson, 1999). For regular characters in Chinese, the phonetic radicals have the same pronunciations as whole compound characters, which may enhance phonological activation and lead to semantic activation by phonology. Such observations point to a phonological use depending on the task materials or demands in Chinese character recognition as well.

In summary, the present study indicates a dual-route framework to explain how to access Chinese character meaning. In this framework, direct access is dominant, while phonology might play a secondary role. This reflects partially a return to the more traditional understanding of visual word recognition for the logographic script. Phonological activation may be automatic but its use may be influenced by character frequency, strategic process, task demands, or specific experimental conditions probing Chinese character meaning. That the importance of phonology is relative as determined by a number of factors seems to be generally true in different languages.

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