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Independent Effects of Orthographic and Phonological Facilitation on Spoken Word Production in Mandarin

Qingfang Zhang[1], **Hsuan-Chih Chen**[2], **Brendan Stuart Weekes**[3], **Yufang Yang**[1]

[1] *State Key Laboratory* of *Brain and Cognitive Science, Institute of Psychology, Chinese Academy of Sciences, Beijing, China*
[2] *The Chinese University of Hong Kong, Hong Kong*
[3] *Department of Psychology, University of Sussex, UK*

Key words

lexical access

Mandarin

picture–word interference paradigm

word production

Abstract

A picture–word interference paradigm with visually presented distractors was used to investigate the independent effects of orthographic and phonological facilitation on Mandarin monosyllabic word production. Both the stimulus-onset asynchrony (SOA) and the picture–word relationship along different lexical dimensions were varied. We observed a pure orthographic facilitation effect and a pure phonological facilitation effect, and found that the patterns of orthographic and phonological facilitation were different. Of most interest, the additive effects of orthographic and phonological facilitation at –150-ms and 0-ms SOAs indicated that the orthographic effect was largely independent of the phonological effect on spoken picture naming. We argue that the present findings are useful for constraining theoretical models of language production and contend that theoretical models of word production need to consider independent effects of orthography and phonology on picture naming, at least in Chinese.

1 Introduction

The picture–word interference task is a widely used paradigm to study the process involved in speech production. In this task, a semantic relationship between a target

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Address for correspondence. Qingfang Zhang, Institute of Psychology, Chinese Academy of Sciences, Datun Road 10A, Chaoyang District, Beijing, 100101, China; <zhangqf@psych.ac.cn>; Hsuan - Chin Chen, Department of Psychology, Chinese university of Hong Kong, Shatin, N.T., Hong Kong S. A. R., China; <hcchen@psy.cuhk.edu.hk>

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picture and a distractor slows response time relative to an unrelated condition, whereas a phonological relationship between a target picture and a distractor speeds responses relative to an unrelated condition (e.g., Glaser & Düngelhoff, 1984; Lupker & Katz, 1981; Schriefers, Meyer, & Levelt, 1990; Starreveld & La Heij, 1995). These two phenomena have been called the semantic interference effect and the phonological facilitation effect, respectively. Both of these effects are an important constraint on models of spoken word production (Levelt, Roelofs, & Meyer, 1999).

One question about the phonological facilitation effect concerns the importance of purely sound based similarity between target and distractor. In most alphabetic languages including English and Dutch, orthography and phonology are unavoidably confounded. With the exception of examples such as *ate* vs. *eight,* words that are phonologically similar typically have substantial overlap in orthography. Lupker (1982), for example, investigated the effects of phonetic and orthographic similarity between the word and the picture's name using a picture–word interference task in English. The results showed that an orthographic similarity condition (e.g., lane–plane) facilitated naming responses by 56 ms, and a phonetic similarity condition (e.g., brain–plane) facilitated naming by approximately 20 ms, while the orthographic plus phonetic similarity condition (e.g., year–bear) led to a 55-ms facilitation in comparison to the unrelated condition. In addition, Underwood and Briggs (1984) found no priming at all from phonetic similarity with substantial priming for the orthographic plus phonetic similarity condition. Both studies suggest that in alphabetic scripts shared orthography and shared phonology might play a different role in picture naming.

Research in alphabetic scripts has manipulated items that are relatively "orthographically related" or "phonologically related" and investigated "orthographic" effects in studies with visual distractors and "phonological" effects with auditory distractors (Damian & Martin, 1999; Schriefers et al., 1990; Starreveld & La Heij, 1995, 1996). However, any phonological effect found with English or Dutch materials will reflect the contribution of shared orthography between the distractor word and the target name. This combined effect raises two questions: one is the relative contribution of the orthographic and phonological factors in a picture–word task. Another is the locus of the combined orthographic and phonological effects (Starreveld & La Heij, 1995). Due to the confounding of orthography and phonology in alphabetic languages, it is difficult to investigate these two questions experimentally. Any effect of phonological facilitation can always be confounded with the automatic activation of target orthography at some level.

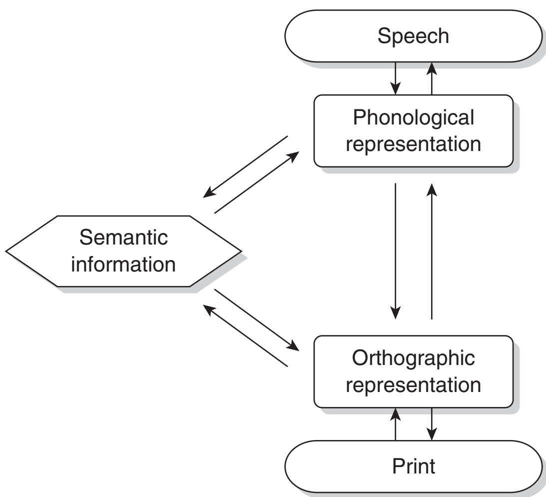
A few behavioral studies suggest that orthographic information is activated automatically in speech production (e.g., Damian & Bowers, 2003; Osborne, Rastle, & Burke, 2004). Damian and Bowers (2003), using a form preparation paradigm, investigated the effect of orthographic activation on single word production. The results showed a reliable priming effect in a homogenous condition in which all response words share initial sound and spelling (e.g., "camel"–"coffee"–"cushion"), with no priming effect in an inconsistent condition in which all response words share initial sound, but differ in spelling (e.g., "camel"–"kayak"–"kidney") and in a heterogeneous condition in which all response words share neither initial sound nor spelling (e.g., "camel"–"gypsy"–"cushion"). Their findings suggest that response words sharing only initial sound cannot produce reliable priming, and that incongruent orthography disrupts the phonological priming effect. Hence, when retrieving the phonological codes of responses words, although orthographic information is irrelevant to speaking process, the orthographic codes impact on speech production. Models of oral reading in alphabetic scripts can explain effects of orthography on production because orthographic representations become automatically activated via feedback connections between phonology and orthography at the lexical level (e.g., Coltheart, Rastle, Perry, Langdon, & Zeigler, 2001).

In non-alphabetic languages such as Chinese, the representations of orthography and phonology are relatively independent (Chen & Juola, 1982). For example, given a picture "bed" (床 in Chinese, /chuang2/), there is a pure orthographically related Chinese character "庆" (/qing4/ in phonetic *pinyin*, meaning *celebration*), with a phonetic pronunciation that is totally dissimilar to the pronunciation of the target; and there is a pure phonologically related Chinese character "创"(/chuang4/, *creation*), with a visual form that is totally dissimilar to that of the target. Thus, it is possible to isolate orthographic and phonological effects independently with a picture–word interference task in Chinese.

As in models of oral reading in alphabetic languages, we can assume a direct lexical connection between orthography and phonology based on data from aphasic patients (Weekes, Chen, & Yin, 1997) and computational models (Perfetti, Liu, & Tan, 2005) in addition to an indirect semantic route that links orthography to phonology via semantic representations. This triangle framework is depicted in Figure 1 (adapted from Weekes et al., 1997). These models assume independent levels of representation for orthography and phonology that are linked via feedback mappings so that facilitation of picture naming in Chinese is theoretically possible if a distractor shares orthography with the target name or shares phonology with the target name or both. These models also allow for independent effects of orthographic and phonological

Figure 1

Functional model of reading and writing in Chinese



facilitation so that if target and distractor share orthography but not phonology or conversely share phonology but not orthography then facilitation will still be observed. Although this theoretical possibility is largely moot in alphabetic languages and will always remain so, the opportunity to test these predictions in Chinese presents itself as an interesting addition to the literature on picture word facilitation.

Weekes, Davies, and Chen (2002) used this opportunity and investigated the independent effects of orthographic and phonological relatedness on picture naming in Chinese. They manipulated items that were orthographically but not phonologically related and items that were phonologically but not orthographically related and found effects of orthographic facilitation on picture naming that were independent of any phonological relation in addition to independent effects of phonological facilitation on picture naming. They also reported that there was no significant interaction between the two factors when pictures and distractors were presented simultaneously, that is, at an SOA of 0 ms. They suggested that the independent orthographic effect was due to the automatic activation of the orthographic representation of the target that fed forward to the name of the target picture to produce a facilitation effect. They also argued that the independent phonological effect was due to activation of the target name via the direct lexical mappings between (unrelated) orthography and phonology. Although these effects supported the predictions described above, Weekes et al. (2002) did not consider whether additive or interactive patterns between orthographic and phonological relatedness occur at different SOAs. This question is important for theoretical reasons because any evidence of interactive (non-additive) effects challenges the claim put forward by Weekes et al. (2002) that orthography and phonology have independent effects on spoken word production in Chinese.

The present study was designed to investigate the patterns of the orthographic and phonological facilitation effects on spoken word production in Mandarin. We used a picture–word interference paradigm similar to the one used by Schriefers et al. (1990) and Starreveld and La Heij (1995, 1996). Participants were required to name a target picture and ignore a distractor word. Five experimental conditions were constructed each with a unique picture–word relationship (i.e., semantically related, phonologically related, orthographically related, orthographically and phonologically related, and unrelated). The onset of a distractor word was varied to occur before (negative SOA), after (positive SOA), or simultaneously with the onset of the target picture, using three levels of SOA (–150 ms, 0 ms, and 150 ms). Furthermore, two main variables (i.e., orthographic and phonological relatedness between the name of a target picture and the corresponding distractor) were factorially manipulated in the experiment as in Weekes et al. (2002).

Our manipulation of SOA allows us to test some predictions about the time course of the facilitatory effects. All models of word recognition assume that orthography is activated before phonological output (e.g., Coltheart, 1978; Forster & Davis, 1991; van Orden, 1987). A few studies of visual word recognition in Chinese provide evidence for this assumption. For example, Chen, Flores d'Arcais, and Cheung (1995), Leck, Weekes, and Chen (1995), as well as Wong and Chen (1999) found robust orthographic effects in the early stage of visual word reading, while Chen and Shu (2001) found a phonological effect occurred in a relatively late stage of visual word reading. Given these findings we expect any independent orthographic facilitation effect to occur before any independent phonological effect. Based on Sternberg's (1969) additive factors logic, assuming that the phonological and orthographic effects arise at independent levels of processing, we would expect to find that their effects are also additive. On the other hand, if the phonological and orthographic effects arise at the same level of processing, we would expect to find non-additive effects.

2 Method

2.1 Participants

Ninety undergraduate students from China Agricultural University participated. All were native speakers of Mandarin Chinese with normal or corrected to normal vision.

2.2 Materials

Twenty target pictures with monosyllabic names were selected from Zhang and Yang's (2003) picture database. Each target was matched with five different distractor words, corresponding to five different distractor types respectively (i.e., orthographically related, phonologically related, orthographically and phonologically related, semantically related, and unrelated). Each semantically related distractor was semantically associated with the corresponding picture in the sense that they belonged to the same semantic category, but they could not be combined with the picture name to form a disyllabic word. In addition, each semantically related word and the name of its corresponding picture did not share the same semantic radical, such as "龟" (/gui1/, *turtle*) and "蛙" (/wa1/, *frog*). The phonologically related words shared the same syllable with the target, but had a different tone and were orthographically and semantically unrelated to the target. The orthographically related distractors were chosen from Han's (1993) feature information database of Chinese characters. Each of them shared the same visual structure and a part of the character with the name of the corresponding picture. They were phonologically and semantically unrelated to the target. Each orthographically and phonologically related distractor shared (a) the same character structure, (b) part of the character component, and (c) the same syllable with the name of the corresponding picture. They were semantically unrelated to the target. The unrelated words were semantically, orthographically, and phonologically unrelated to the picture names. A complete list of target pictures and distractor words are shown in the Appendix. Distractors in different conditions were carefully matched for the number of strokes and for their written word frequency based on normative information reported by the Beijing Language Institute (1986). Pair-wise comparisons revealed that the mean frequencies of words in various conditions were not significantly different from each other. As an example, five distractor types for the picture "bed" and the means of strokes and the median frequencies of written word of all stimuli and distractor are shown in Table 1.

Table 1

Examples of stimuli used in the experiment and the means of word complexity (number of strokes) and the median frequencies of written word (per million)

		Distractor type				
		Orth-pho related	*Semantically related*	*Orthographically related*	*Phonologically related*	*Unrelated*
	床	疮	枕	庆	创	麦
Meaning	bed	sore	pillow	celebration	creation	wheat
Phonetics	/chuang2/	/chuang1/	/zhen3/	/qing4/	/chuang4/	/shen1/
Median frequency	91	20	54	41	47	64
Number of strokes	10.10	9.80	9.80	9.35	9.00	10.40

Note: orth-pho = orthographic-phonologically related.

2.3 Design

The design included a within-subjects factor distractor type with five levels and a between-subjects factor SOA with three levels: –150 ms, 0 ms, 150 ms. Each participant saw 20 target pictures five times. In addition, in order to avoid each picture being seen too many times by each participant, SOA was selected as a between-subjects variable. The combination of target and distractor word was presented using three SOAs. Because there were 20 targets, each presented in five different interfering conditions, the experiment contained 100 different interfering word and target combinations. Fifteen practice pictures were presented twice with two unrelated words, so the experimental trials were preceded by 30 practice trials. The 30 practice trials were followed by 100 experimental trials per series, presented in a pseudorandom order. To reduce possible repetition effects due to repeated presentation of the same picture, the presentation of a target picture was always separated by the presentation of at least five other pictures. Participants were trained to familiarize themselves with the experiment procedure. The practice pictures were different from the target pictures in the experiment.

2.4 Apparatus

The experiment was programmed using E-Prime Professional Software (Beta 4.0). Presentation of stimuli and collection of reaction times was performed using a fast Pentium-compatible PC. The pictures were presented on a high-resolution monitor (800 × 600). The response was recorded by a microphone, which was connected with the computer via a PST Serial Response Box.

2.5 Procedure

Participants were tested individually. They sat in a dimly lit room at a comfortable viewing distance in front of the computer. Before the experiment, participants were told that their task was to name the pictures. First, the participants were familiarized with the set of experimental pictures by viewing each target picture for 3000 ms with the picture name printed below each picture. Then, 35 pictures (15 for practice and 20 for experiment) were presented on the computer screen successively for the participants to give the names of the pictures. If their responses were not as expected, the experimenter corrected them until the participants could name the pictures with the correct words. Finally, the experimental blocks were administered with 30 practice trials and 100 experimental trials in each block.

Each trial involved the following sequence: A fixation point (+) presented in the middle of the screen for 500 ms, followed by a blank screen for 500 ms. After that the first stimulus (i.e., either the distractor word or the target picture) appeared, then the second one appeared after a pre-specified SOA. Then, the word and the picture were presented until the participant made a vocal response. The participants were asked to name the picture as quickly as possible, while ignoring the word as best as they could. Following each naming response, the experimenter judged the response to be correct or not. The interval between two trials was 2000 ms.

3 Results

Picture naming times from incorrect and other responses were removed. Naming latencies longer than 1500 ms or shorter than 200 ms and those deviating by more than three standard deviations from their cell means were also discarded. The above three criteria accounted for 2.1%, 1.2%, and 1.3% of the data respectively. All analyses were performed on the remaining data. Table 2 shows the means and error percentages for each condition.

Table 2

Participant reaction times means (ms) per condition and error percentage

Distractor types	*SOAs*					
	–150 MS		*0 MS*		*150 MS*	
	M	*% error*	*M*	*% error*	*M*	*% error*
Semantic	740	3.50	716	4.50	668	5.33
Orth-pho	641	0.33	612	1.00	632	1.33
Phonological	697	0.67	646	1.33	652	2.00
Orthographic	659	2.50	630	1.00	632	2.00
Unrelated	701	1.33	683	2.17	676	2.17

Note: M = mean; orth-pho = orthographic-phonologically related.

An ANOVA (*F1*) was conducted per participant with distractor type as a within-subjects factor and SOA as a between-subjects factor. The item analysis (*F2*) was performed with both distractor type and SOA as within-items factors. For naming latencies analyses, the SOA effect was not significant in the participant analysis $F1(2, 87) = 1.55$, $p < .22$, but significant in the item analysis $F2(2, 38) = 21.55$, $p < .001$. The effect of distractor type was significant $F1(4, 348) = 113.24$, $p < .001$; $F2(4, 76) = 25.17$, $p < .001$, and the interaction of SOA and distractor type was significant in the participant analysis $F1(8, 348) = 7.96$, $p < .001$, but not in the item analysis $F2(8, 152) = 1.19$, $p < .31$. Newman-Keuls pair-wise comparisons were conducted to compare the unrelated condition with other conditions. The results showed that the semantic interference effect occurred at –150-ms and 0-ms SOAs, both *p*s < .05, whereas the phonological facilitation effect appeared at 0-ms and 150-ms SOAs, both *p*s < .05. The orthographic facilitation effect and orth-pho facilitation effect were significant at SOAs ranging from –150 ms to 150 ms, all *p*s < .05.

For error rates analyses, the SOA effect was significant in the participant analysis $F1(2, 87) = 3.95$, $p < .05$, but not in the item analysis $F2(2, 38) = 2.75$, $p < .08$. The effect of distractor type was significant $F1(4, 348) = 17.48$, $p < .001$; $F2(4, 76) = 5.97$, $p < .001$. The interaction of SOA and distractor type was not significant in both analyses $F1(8, 348) = 1.02$, $p < .43$; $F2(8, 152) = 0.44$, $p < .90$. No other effects were significant.

Because orthographic relatedness and phonological relatedness were factorially manipulated, two additional ANOVAs were conducted on the data, excluding those from the semantically-related condition. In these analyses, the unrelated condition was treated as orthographically and phonologically unrelated. For the participant analyses, there were two within-subjects factors (orthographic relatedness and phonological relatedness) and one between-subjects factor (SOA). For the item analyses, there were three within-items factors: orthographic relatedness, phonological relatedness, and SOA.

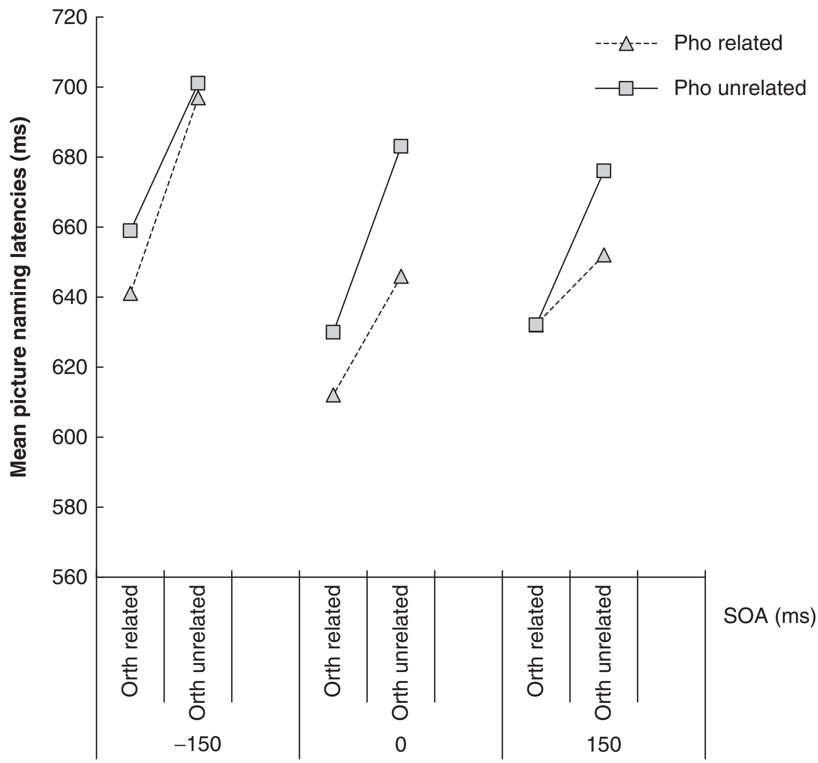
For naming latencies analyses, the effect of SOA was not significant in the participant analysis $F1(2, 87) = 1.25$, $p < .30$, but was significant in the item analysis $F2(2, 38) = 17.03$, $p < .001$. The effect of orthographic relatedness was significant $F1(1, 87) = 207.49$, $p < .001$, $F2(1, 19) = 31.31$, $p < .001$. The effect of phonological relatedness was significant $F1(1, 87) = 36.61$, $p < .001$; $F2(1, 19) = 9.24$, $p < .01$. The interaction of SOA and phonological relatedness was significant in the participant analysis $F1(2, 87) = 3.44$, $p < .05$, but not in the item analysis $F2(2, 38) = 0.80$, $p < .46$. The interaction of SOA and orthographic relatedness was marginally significant in the participant analysis $F1(2, 87) = 3.00$, $p < .06$, but not in the item analysis $F2(2, 38) = 0.59$, $p < .60$. The interaction of orthographic relatedness and phonological relatedness was not significant in either analysis $F1(1, 87) = 2.56$, $p < .12$; $F2(1, 19) = 0.81$, $p < .39$.

More crucially, the three-way interaction (SOA × phonological relatedness × orthographic relatedness) was significant in the participant analysis $F1(2, 87) = 4.07$, $p < .05$, but not in the item analysis $F2(2, 38) = 1.05$, $p < .36$. This three-way interaction revealed that different patterns of phonological relatedness by orthographic relatedness were observed across various SOAs (see Figure 2 for the two-way effects as a function of SOA). Specifically, the interaction of orthographic relatedness and phonological relatedness was significant at the 150-ms SOA $F1(1, 29) = 10.61$, $p < .01$; $F2(1, 19) = 1.66$, $p < .22$. However, this interaction was not significant at –150-ms

$F1(1, 29) = 1.24$, $p < .28$; $F2(1, 19) = 0.39$, $p < .55$ or 0-ms SOA $F1(1, 29) = 3.30$, $p < .09$; $F2(1, 19) = 1.21$, $p < .29$. The analyses on error rates showed only a significant effect of phonological relatedness in the participant analysis $F1(1, 87) = 8.98$, $p < .01$. No other effects were significant.

Figure 2

Phonological and orthographic facilitation effects as a function of SOA



4 Discussion

The present study investigated (1) the patterns of the orthographic and phonological effects in Chinese picture naming at different SOAs, and (2) whether there is an interaction between orthographic and phonological relatedness at different SOAs using a picture–word interference task. The findings can be summarized as follows. First, we found a pure orthographic facilitation effect and a pure phonological facilitation effect as reported by Weekes et al. (2002); however, the patterns were very different across SOA. Second, the orthographic effect was independent from the phonological effect at the 0 ms SOA as reported by Weekes et al. (2002). However, there was evidence of interactive effects between orthography and phonology on picture naming at an SOA of 150 ms.

Specifically, the results revealed that a phonological facilitation effect occurred between 0-ms and 150-ms SOAs, and an orthographic facilitation effect spanned a range of SOAs from –150 ms to 150 ms. The magnitude of the phonological effect was comparable to that found in other studies (e.g., Lupker, 1982; Rayner & Springer, 1986; Starreveld & La Heij, 1995, 1996), but was smaller than the magnitude of the orthographic effect. The results also showed that the phonological effect decayed faster than the orthographic effect. The orthographic effects were almost the same across the SOA intervals: It was 60 ms at –150-ms SOA, 53 ms at 0-ms SOA, and 44 ms at 150-ms SOA. However, the phonological effects decreased quickly: The maximum was 43 ms at 0-ms SOA, and 24 ms at 150-ms SOA. The decreasing tendency of the orthographic-phonological facilitation effects was as follows: The maximum was 71 ms at 0-ms SOA, 60 ms at –150-ms SOA, and 44 ms at 150-ms SOA. Clearly, the orthographic effects were generally compatible with the orthographic-phonological effects at different SOAs. In short, relative to the phonological effect, the orthographic effect not only appeared earlier and lasted longer, but its magnitude was also larger than that of the phonological effect.

The mentioned results are particularly interesting for the following reasons. First, the picture naming task adopted in the present study demands the use of phonological information, but not orthographic information. Second, the degree of phonological similarity between distractors and picture names is actually higher than the degree of orthographic similarity. This is because the phonologically related words differed only in tone, which is often neglected in behavioral tasks such as syllable comparison for auditory stimuli (Cutler & Chen, 1997) and homophone judgment for written characters (Taft & Chen, 1992), whereas the orthographically related characters differed in a major radical, which is rather distinct. Thus, one might expect to find a more prominent phonological effect in picture naming. However, an opposite pattern of results was found. Since speech production in Chinese has rarely been investigated, the mentioned results provide important new evidence for the idea that orthographic information plays a particularly important role in Chinese language processing (e.g., Chen et al., 1995; Chen & Shu, 2001; Wong & Chen, 1999).

Another striking finding of the present study is the absence of an interaction between orthographic and phonological facilitation on picture naming at –150-ms and 0-ms SOAs. At –150-ms SOA, the orthographic-phonological facilitation effect was 60 ms, the orthographic effect was 42 ms, and the phonological effect was negligible (4 ms). Also, at 0-ms SOA, the orthographic-phonological facilitation effect was 61 ms, the orthographic effect was 53 ms, and the phonological effect was 37 ms. It appears that the orthographic effects were generally compatible with the orthographic-phonological effects and all of them were clearly larger than the phonological effects. The present findings at 0-ms SOA are consistent with those reported by Weekes et al. (2002), indicating that these are robust results. Taken together these results suggest that orthographic and phonological effects in picture naming in Chinese are additive in general and might arise at independent levels during picture naming as depicted in Figure 1.

Still another notable result is the interaction between orthographic and phonological relatedness at 150-ms SOA, suggesting that the orthographic and phonological facilitation effects are non-additive at this particular SOA. The effect of phonological relatedness was attenuated when there was an orthographic relation between distractors and picture names. Damian and Bowers (2003)'s study found that orthographic codes may be activated when retrieving the phonological coding of the responses words. Hoshino and Kroll (2007) suggested that all lexical codes are connected bi-directionally in lexical processing such that orthography modulates phonological processing during spoken word production. In addition, established models of visual word recognition assume that there are strong bi-directional interactions between orthographic and phonological representations, and Coltheart et al. (2001) implemented this assumption in a number of computational models. Although computational models of oral reading in Chinese do not require automatic feedback between orthography and phonology during lexical processing in Chinese (see Perfetti et al., 2005, for discussion), the framework in Figure 1 allows feedback to occur. We contend, therefore, that the orthographic and phonological information was co-activated at a later stage of word production during the experiment.

In sum, the present study demonstrated a pure orthographic facilitation effect and a pure phonological effect, and the results indicated that the pattern of effects was very different across SOAs. More importantly, the additive effects of orthographic and phonological relatedness at –150-ms and 0-ms SOAs indicated that orthographic facilitation is largely independent from the phonological facilitation in the picture–word interference task, though interactive effects might appear at later SOAs. Our results further suggest that theoretical models of word production need to consider the effects of orthography and phonology on picture naming independently, at least in Chinese.

References

BEIJING LANGUAGE INSTITUTE (1986). *Modern Chinese frequency dictionary (in Chinese)*. Beijing: Beijing Language Institute Publisher.

CHEN, H.-C., FLORES d'ARCAIS, G. B., & CHEUNG, S. L. (1995). Orthographic and phonological activation in recognizing Chinese characters. *Psychological Research*, **58**, 144–153.

CHEN, H.-C., & JUOLA, J. F. (1982). Dimensions of lexical coding in Chinese and English. *Memory and Cognition*, **10**, 216–224.

CHEN, H.-C., & SHU, H. (2001). Lexical activation during the recognition of Chinese characters: Evidence against early phonological activation. *Psychonomic Bulletin & Review*, **8**, 511–518.

COLTHEART, M. (1978). Lexical access in simple reading tasks. In G. Underwood (ed.), *Strategies of information processing* (pp.151–216). London: Academic Press.

COLTHEART, M., RASTLE, K., PERRY, C., LANGDON, R., & ZIEGLER, J. (2001). DRC: A dual route cascaded model of visual word recognition and reading aloud. *Psychological Review*, **108**, 204–256.

CUTLER, A., & CHEN, H.-C. (1997). Lexical tone in Cantonese spoken-word processing. *Perception and Psychophysics*, **59**, 165–179.

DAMIAN, M. F., & BOWERS, J. S. (2003). Effects of orthography on speech production in a form-preparation paradigm. *Journal of Memory and Language*, **49**, 119–132.

DAMIAN, M. F., & MARTIN, R. C. (1999). Semantic and phonological codes interact in single word production. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **25**, 345–361.

FORSTER, K. L., & DAVIS, C. (1991). The density constraint on form-priming in the naming task: Interference effects from a masked prime. *Journal of Memory and Language*, **30**, 1–25.

GLASER, W. R., & DÜNGELHOFF, F. J. (1984). The time course of picture–word interference. *Journal of Experimental Psychology: Human Perception and Performance*, **10**, 640–654.

HAN, B. (1993). Application of the feature information database of Chinese characters in the research of Chinese character recognition (in Chinese). *Journal of Developments in Psychology*, **1**, 29–35.

HOSHINO, N., & KROLL, J. F. (2007). Cognate effects in picture naming: Does cross-language activation survive in a change of script? *Cognition*, **106**, 501–511.

LECK, K. J., WEEKES, B. S., & CHEN, M. J. (1995). Visual and phonological pathways to the lexicon: Evidence from Chinese readers. *Memory and Cognition*, **23**, 468–476.

LEVELT, W. J. M., ROELOFS. A., & MEYER, A. S. (1999). A theory of lexical access in speech production. *Behavioral and Brain Sciences*, **22**, 1–75.

LUPKER, S. J. (1982). The role of phonetic and orthographic similarity in picture–word interference. *Canadian Journal of Psychology*, **26**, 349–367.

LUPKER, S. J., & KATZ, A. N. (1981). Input, decision, and response factors in picture–word interference. *Journal of Experimental Psychology: Human Learning and Memory*, **7**, 269–282.

OSBORNE, G., RASTLE, K., & BURKE, D. (2004). *Phonological and orthographic effects on picture naming*. Poster presented at the 45th Annual Meeting of Psychonomic Society, Minneapolis, MN, November, 2004.

PERFETTI, C. A., LIU, Y., & TAN, L. H. (2005). The lexical consistency model: Some implications of research on Chinese for general theories of reading. *Psychological Review*, **112**, 43–59.

RAYNER, K., & SPRINGER, C. J. (1986). Graphemic and semantic similarity effects in the picture–word interference task. *British Journal of Psychology*, **77**, 202–222.

SCHRIEFERS, H., MEYER, A. S., & LEVELT, W. J. M. (1990). Exploring the time course of lexical access in language production: Picture–word interference studies. *Journal of Memory and Language*, **29**, 86–102.

STARREVELD, P. A., & LA HEIJ, W. (1995). Semantic interference, orthographic facilitation, and their interaction in naming tasks. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **21**, 686–698.

STARREVELD, P. A., & LA HEIJ, W. (1996). Time-course analysis of semantic and orthographic context effects in picture naming. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **22**, 896–918.

STERNBERG, S. (1969). The discovery of processing stages: Extension of Donders' method. *Acta Psychologia*, **30**, 276–315.

TAFT, M., & CHEN, H.-C. (1992). Judging homophony in Chinese: The influence of tone. In H-C. Chen & O. Tzeng (Eds.), *Language processing in Chinese* (pp.151–172). Amsterdam: Elsevier.

UNDERWOOD, G., & BRIGGS, P. (1984). The development of word recognition processes. *British Journal of Psychology*, **75**, 243–255.

van ORDEN, G. C. (1987). A ROWS is a ROSE: Spelling, sound and reading. *Memory and Cognition*, **15**, 181–198.

WEEKES, B. S., CHEN, M.-J., & YIN, W.-G. (1997). Anomia without dyslexia in Chinese. *Neurocase*, **3**, 51–60.

WEEKES, B., DAVIES, R., & CHEN, M. J. (2002). Picture–word interference effects on naming in Chinese. In H. S. R. Kao, C. K. Leong, & D.-G. Gao (Eds.), *Cognitive Neurosciences Studies of the Chinese Language*, (pp.101–127). Hong Kong University Press.

WONG, K. F. E., & CHEN H.-C. (1999). Orthographic and phonological in reading Chinese text: Evidence from eye fixation. *Language and Cognitive Processes*, **14**, 461–480.

ZHANG, Q., & YANG, Y. (2003). The determiners of picture naming latency (in Chinese). *Acta Psychologica Sinica*, **35**, 447–454.

Appendix A

Stimuli used in Experiment

Picture name	*Orthographic-phonologically related distractor*	*Semantically related distractor*	*Orthographically related distractor*	*Phonologically related distractor*	*Unrelated distractor*
狗 (/gou3/, *dog*)	枸 (/gou1/, *twisted roots*)	马 (/ma3/, *horse*)	拘 (/ju1/, *limitation*)	钩 (/gou1/, *hook*)	帛 (/bo2/, *silk*)
针 (/zhen1/, *needle*)	镇 (/zhen4/, *town*)	布 (/bu4/, *cloth*)	叶 (/ye4/, *leaf*)	疹 (/zhen3/, *measles*)	蒜(/suan4/, *garlic*)
猪 (/zhu1/, *pig*)	诸 (/zhu1/, *a surname*)	羊 (/yang2/, *goat*)	赌 (/du3/, *bet*)	柱 (/zhu4/, *pillar*)	晨 (/chen2/, *morning*)
床 (/chuang2/, *bed*)	疮 (/chuang1/, *sore*)	枕 (/zhen3/, *pillow*)	庆 (/qing4/, *celebration*)	创 (/chuang4/, *creation*)	麦 (/mai4/, *wheat*)
鹿 (/lu4/, *deer*)	庐 (/lu2/, *hut*)	狼 (/lang2/, *wolf*)	席 (/xi2/, *mat*)	颅 (/lu2/, *skull*)	谜 (/mi2/, *enigma*)
剑 (/jian4/, *sword*)	俭 (/jian3/, *frugality*)	棍 (/gun4/, *stick*)	脸 (/lian3/, *face*)	茧 (/jian3/, *cocoon*)	茶 (/cha2/, *tea*)
糖 (/tang2/, *candy*)	塘 (/tang2/, *pond*)	酒 (/jiu3/, *wine*)	粉 (/fen3/, *powder*)	堂 (/tang2/, *hall*)	薪 (/xin1/, *salary*)
梨 (/li2/, *pear*)	犁 (/li2/, *furrow*)	枣 (/zao3/, *Chinese date*)	染 (/ran3/, *dye*)	理 (/li3/, *theory*)	梯 (/ti1/, *ladder*)
碗 (/wan3/, *bowl*)	豌 (/wan1/, *pea*)	叉 (/cha4/, *fork*)	碇 (/ding4/, *a heavy stone used as an anchor*)	湾 (/wan1/, *bay*)	幕 (/mu4/, *curtain*)
狐 (/hu2/, *fox*)	弧 (/hu2/, *arc*)	鹿 (/lu4/, *deer*)	呱 (/gua1/, *croak*)	湖 (/hu2/, *lake*)	茔 (/ying2/, *grave*)

(Continued)

Appendix A (Continued)

Picture name	*Orthographic-phonologically related distractor*	*Semantically related distractor*	*Orthographically related ristractor*	*Phonologically related distractor*	*Unrelated distractor*
桥 (/qiao2/, *bridge*)	峤 (/qiao2/, *high mountain*)	栏 (/lan2/, *railing*)	轿 (/jiao4/, *bamboo carriage*)	壳 (/qiao4/, *shell*)	盐 (/yan2/, *salt*)
哨 (/shao4/, *whistle*)	梢 (/shao1/, *thin end of a branch*)	箫 (/xiao1/, *a vertical bamboo flute*)	硝 (/xiao1/, *saltpetre*)	勺 (/shao2/, *spoon*)	唐 (/tang2/, *Tang Dynasty*)
耙 (/pa2/, *harrow*)	杷 (/pa2/, *a kind of fruit*)	锹 (/qiao1/, *shovel*)	靶 (/ba3/, *target*)	帕 (/pa4/, *handkerchief*)	扇 (/shan4/, *fan*)
钳 (/qian2/, *pliers*)	铅 (/qian1/, *lead*)	剪 (/jian3/, *scissors*)	柑 (/gan1/, *mandarin orange*)	堑 (/qian4/, *chasm*)	症 (/zheng1/, *disease*)
桃 (/tao2/, *peach*)	洮 (/tao2/, *tao river*)	橙 (/cheng2/, *orange*)	姚 (/yao2/, *a kind of surname*)	涛 (/tao1/, *billow*)	畜 (/chu4/, *domestic animal*)
钉 (/ding1/, *nail*)	玎 (/ding1/, *tinkle*)	锯 (/ju4/, *saw*)	灯 (/deng1/, *lamp*)	鼎 (/ding3/, *an ancient cooking vessel*)	亩 (/mu3/, *a unit of area*)
锤 (/chui2/, *hammer*)	陲 (/chui2/, *borders*)	斧 (/fu3/, *ax*)	唾 (/tuo4/, *saliva*)	炊 (/chui1/, *cooking*)	雷 (/lei2/, *thunder*)
鸭 (/ya1/, *duck*)	鸦 (/ya1/, *crow*)	鹰 (/ying1/, *eagle*)	鸣 (/ming2/, *chirp*)	芽 (/ya2/, *bud*)	庙 (/miao4/, *temple*)
椅 (/yi3/, *chair*)	猗 (/yi1/, *castrated dog*)	桌 (/zhuo1/, *table*)	崎 (/qi2/, *be rugged and rough*)	衣 (/yi1/, *clothes*)	舜 (/shun4/, *a kind of grass*)
炮 (/pao4/, *cannon*)	泡 (/pao4/, *bubble*)	枪 (/qiang1/, *gun*)	胞 (/bao1/, *embryo*)	抛 (/pao1/, *throwing*)	茶 (/cha2/, *tea*)