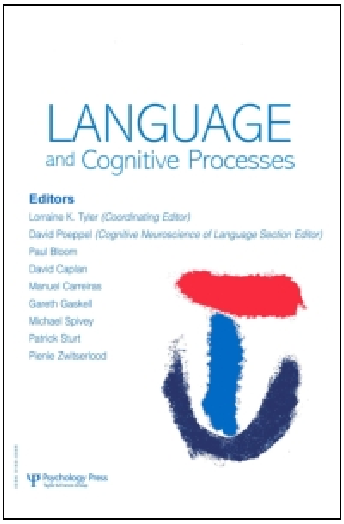

Language and Cognitive Processes
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713683153

Orthographic facilitation effects on spoken word production: Evidence from Chinese

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To cite this Article Zhang, Qingfang and Weekes, Brendan Stuart(2009) 'Orthographic facilitation effects on spoken word production: Evidence from Chinese', Language and Cognitive Processes, 24: 7, 1082 — 1096
To link to this Article: DOI: 10.1080/01690960802042133
URL: http://dx.doi.org/10.1080/01690960802042133

LANGUAGE AND COGNITIVE PROCESSES
2009, 24 (7/8), 1082–1096

Psychology Press
Taylor & Francis Group

Orthographic facilitation effects on spoken word production: Evidence from Chinese

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The aim of this experiment was to investigate the time course of orthographic facilitation on picture naming in Chinese. We used a picture-word paradigm to investigate orthographic and phonological facilitation on monosyllabic spoken word production in native Mandarin speakers. Both the stimulus-onset asynchrony (SOA) and the picture-word relationship were varied along different lexical dimensions including measures of orthographic similarity between the distractor and the target and measures of phonological similarity between the distractor and target. Results showed independent effects of orthographic and phonological facilitation that varied across SOA. Specifically, orthographic facilitation was observed prior to phonological facilitation. We argue that theoretical models of spoken word production need to explain the independent effects of orthography on picture naming in Chinese as well as the variable time course. The implication of orthographic facilitation effects on speech production in other languages is also discussed.

The picture-word task is a widely used paradigm to study the cognitive processes involved in speech production. In this task, a phonological relationship between a written word distractor such as key and a target picture such as cat speeds naming relative to an unrelated condition (Glaser

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This research was supported by grants from the National Natural Science Foundation of China (30400134) and the Young Scientist foundation of Institute of Psychology (07CX102010) to Qingfang Zhang, the Universities in China Committee in London to Qingfang Zhang and Brendan Weekes.

http://www.psypress.com/lcp DOI: 10.1080/01690960802042133

& Düngelhoff, 1984; Lupker & Katz, 1981; Schriefers, Meyer, & Levelt, 1990; Starreveld & La Heij, 1995). This phenomenon is called the *phonological facilitation effect* and has been an important constraint on models of production (Levelt, Roelofs, & Meyer, 1999). One question about the phonological facilitation effect concerns the locus of the effect in the speech production system. One hypothesis is that facilitation results from sound similarity between distractor and target e.g., initial phoneme /k/ in key and cat. An alternative hypothesis is that phonological facilitation results from orthographic similarity between distractors and targets in alphabetic languages (e.g., English and Dutch). In all alphabetic languages, orthography and phonology are mostly confounded. With the exception of examples such as *ate* and *eight*, words that are phonologically similar overlap in orthography, e.g. *mustard* and *custard*.

Several experimenters have contrasted effects of phonological and orthographic similarity. Lupker (1982) contrasted phonological and orthographic similarity in English by including (a) an orthographic similarity condition with overlapping letters that have contrasting pronunciations e.g., *year* – *bear*; (b) a phonological similarity condition with overlapping sound (homophony) represented by contrasting letters e.g., *brain* – *plane*; and (c) a condition with both orthographic and phonological similarity e.g., *lane* – *plane*. Lupker (1982) found that facilitation was greatest in condition (a) when compared to an unrelated condition. Underwood and Briggs (1984) also reported priming for an orthographic similarity condition as well as no priming in a phonological similarity condition. Both studies concluded that the phonological facilitation effect may result from an independent effect of orthographic similarity between distractors and targets.

Research in alphabetic scripts comparing orthographic and phonological similarity between a distractor and target is limited to manipulating items that are only relatively orthographically or phonologically related (Lupker, 1982). Related studies investigating orthographic effects using auditory distractors (Damian & Bowers, 2003; Damian & Martin, 1999; Osborne, Rastle, & Burke, 2004; Starreveld & La Heij, 1995, 1996; Schriefers et al., 1990) suggest that orthographic information is activated automatically in speech production in English speakers. For example, Damian and Bowers (2003) using form preparation reported orthographic effects on spoken word production. Their results showed a reliable priming effect in a condition in which all words shared both initial sound and spelling e.g., 'camel' – 'coffee' – 'cushion', with no priming in a condition in which all response words share the initial sound, but differ in spelling e.g., 'camel' – 'kayak' – 'kidney' and no priming in a heterogeneous condition in which words do not share initial sound or spelling, e.g., 'camel' – 'gypsy' – 'cushion'. Damian and Bowers (2003) made the strong claim that words sharing initial sound only do not produce reliable priming and moreover that incongruent orthography disrupts phonological priming. Hence, when participants are asked to retrieve phonological codes in response words, orthographic codes have an impact on speech production (see also Osborne et al., 2004). Reported effects of orthographic facilitation on speech production thus raise important theoretical questions about (a) the relative contribution of orthographic and phonological similarity in the picture-word task; (b) the locus of orthographic and phonological effects; and (c) their possible interactions in the production system (Starreveld & La Heij, 1995). Answers to these questions will have consequences for all models of speech production as well as extant interpretations of the phonological facilitation effect. For example most accounts of phonological facilitation assume that this effect occurs at the level of phonological retrieval only (Starreveld & La Heij, 1995, 1996).

Effects of orthographic facilitation are not necessarily a problem for models of production. All theories of speech production (e.g., Levelt et al., 1999) can account for these effects because models of oral reading in alphabetic scripts assume that phonological representations are automatically activated via connections between phonology and orthography (e.g., Coltheart, Rastle, Perry, Langdon, & Zeigler, 2001). If orthography automatically activates phonology e.g., /k/ priming cat, then orthographic facilitation could be explained as facilitation at the level of name retrieval (Starreveld & La Heij, 1995, 1996). Moreover facilitation effects such as *year* priming *bear* may be explained via activation of a lexical-semantic reading pathway that contains the concept for bear activated by the shared letters *ear*. In the latter case there should be no phonological priming from *ear* in year to bear. Thus, even if orthography has an independent effect on speech production, current cognitive models could explain these effects quite easily.

In our view it is difficult to make strong theoretical claims about orthographic facilitation by studying alphabetic languages. Instead, differences in the relationship between orthography and phonology across languages allow a stronger test of orthographic effects on naming. A small number of researchers have used this cross-script approach (Bi, Xu, & Caramazza, 2008; Weekes, Davies, & Chen, 2002; Zhang, Chen, Weekes, & Yang, in press). Non-alphabetic scripts contain representations of orthography and phonology that can be isolated. For example, in Chinese the target bed 床/chuang2/ shares orthographic similarity with other characters e.g., 庆(/qing4/, meaning celebration) that are pronounced differently to the target and also contains homophonic similarity with other characters 创(/chuang4/, meaning creation), that are visually dissimilar to the target. Thus it is relatively easy to isolate putative independent effects of orthographic and phonological facilitation using the picture-word paradigm in Chinese speakers.

How can studying Chinese speakers be relevant to understanding theoretical models of speech production across languages? Although Chinese is a non-alphabetic language, models of oral reading in Chinese allow orthography to have an effect on name production as in models of oral reading in alphabetic languages. The triangle framework illustrated in Figure 1 (taken from Weekes, Chen, & Yin, 1997) assumes a direct lexical connection between orthography and phonology (depicted on the right side of the figure), as in models of oral reading in English, as well as a pathway that links orthography to phonology via semantic (meaning) representations (left side of the figure). These assumptions are based on data from aphasic speakers (Weekes et al., 1997) and are now shared with current computational models (Perfetti, Liu, & Tan, 2005).

As in models of oral reading in English, the framework in Figure 1 assumes representations for orthography and phonology that are independent but are linked via feedforward and feedback mappings – thus allowing picture name facilitation in Chinese. Critically, the framework allows independent orthographic and phonological facilitation effects because if a target and distractor share orthography but not phonology then facilitation can occur via the lexical semantic pathway and if the target and distractor share phonology but not orthography then facilitation is possible via the

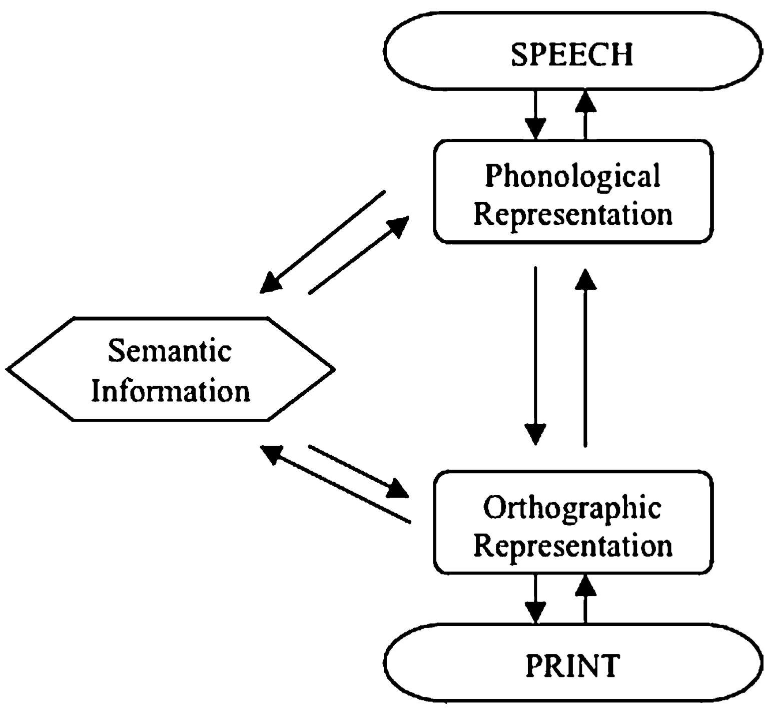

Figure 1. Functional model of reading and writing in Chinese.

direct pathway. According to the name retrieval view of phonological facilitation effects, facilitation from orthography might simply reflect the close connections between orthography and phonology in alphabetic languages. However, an alternative possibility is that orthographic facilitation results from priming at the level of the lexical semantic pathway (depicted in Figure 1). Although this alternative possibility cannot readily be tested in alphabetic languages (with the exception of items such as *year* and *bear*), the opportunity to test these predictions in Chinese can be informative to models of naming. This is because models of oral reading in both Chinese and English share the assumption of a lexical semantic and a direct pathway.

Weekes et al. (2002) were the first to investigate the effects of orthographic and phonological similarity on picture naming in Chinese. They reported orthographic facilitation on naming that was independent of phonological similarity with a distractor e.g., superimposing the character 庆/qing4/ facilitated the naming of a target picture of a bed, which is written as 床/chuang2/ and phonological facilitation effects on naming e.g., superimposing the character 创/chuang4/ also facilitated naming a picture of a bed. They also reported that orthographic and phonological facilitation did not interact when the distractors were presented simultaneously with the target i.e., at an SOA of 0 ms. Weekes et al. suggested that orthographic facilitation effects are due to activation of the target at the level of orthographic representation, which then feeds forward to the target picture name to produce facilitation. They also argued phonological facilitation is due to target name activation between (unrelated) orthography and phonology (see also Zhang et al., in press). In a quite similar study, Bi, Xu, and Caramazza (2008) also reported substantial priming from an orthographic and a phonological similarity condition but unlike Weekes et al. (2002) there was no interaction between orthographic and phonological similarity i.e., no advantage of phonological similarity over orthographic similarity on naming.

In addition to behavioural facilitation effects, Weekes, McMahon, Eastburn, Bryant, Wang, and De Zubicaray (2005) reported a brain imaging study investigating orthographic and phonological facilitation on picture naming in Chinese. The question they asked was whether orthographic and phonological facilitation effects have different neural loci. Weekes et al. reported significant BOLD (blood-oxygen level dependent) signal decreases in an orthographically related (not phonologically related) condition in the left hemisphere inferior frontal lobe, temporal pole and lingual gyrus and right hemisphere thalamus, middle temporal gyrus, temporal pole, angular gyrus, and the supramarginal gyrus. BOLD signal increases were also observed for the orthographic condition in the right hemisphere middle occipital gyrus, inferior parietal lobe, precuneus and supramarginal gyrus. By contrast, BOLD signal decreases in the phonologically related (and not orthographically related) condition were observed in left hemisphere post central gyrus. BOLD signal increases were also observed in the phonological condition in precuneus, thalamus, and supramarginal gyrus in the right hemisphere. Critically, if BOLD signal change during phonological processing was compared with orthographic processing, the phonologically related condition produced more activation in the left hemisphere angular gyrus, middle occipital gyrus, insula and hippocampus and right hemisphere temporal pole and middle temporal gyrus as well as superior frontal gyrus and thalamus bilaterally. By contrast, the orthographically related condition produced more activation in left precuneus and supplementary motor area, the right hemisphere cingulum and middle temporal gyrus as well as supramarginal gyrus and angular gyrus bilaterally. Thus independent effects orthographic and phonological facilitation effects are realised in spatially segregated brain regions. As all studies presented distractors and target simultaneously, one question that arises is whether orthographic and phonological facilitation effects occur at temporally segregated SOAs. This question is of theoretical interest because evidence of interactive effects across SOA is assumed to reflect independent processing stages in naming (Damian & Martin, 1999; Starreveld & La Heij, 1995, 1996).

Our primary aim here was to investigate the time course of orthographic facilitation on picture naming in Chinese. We used the picture-word paradigm developed by Schriefers et al. (1990) and Starreveld and La Heij (1995, 1996). Participants were required to name a target picture and ignore the distractor. We manipulated stimulus onset asynchrony so that the onset of a distractor occurred before the onset of the target, after the onset of the target, or simultaneously (0 ms) with the onset of the target picture as in all extant studies of picture naming in Chinese speakers.

All models of oral reading including Figure 1 assume that orthography will be activated before phonological output (Coltheart, 1978; van Orden, 1987). This assumption is supported by studies of character recognition. For example, Leck, Weekes, and Chen (1995) and also Wong and Chen (1999) report an early orthographic effect in written word recognition, and Chen and Shu (2001) found a phonological effect at a relatively late stage of processing. We therefore expected effects of orthographic facilitation to occur before phonological facilitation i.e., at an earlier SOA and effects of phonological facilitation to occur subsequent to orthographic facilitation. We expected to observe these effects at different stages of word production i.e. different SOAs, given results from Weekes et al. (2002). However, reports of an interaction between effects of orthographic and phonological facilitation reported by Bi et al. (2008) also allow for the alternative outcome i.e., that facilitation effects will co-occur at one or more SOAs.

METHOD

Participants

One hundred and ten undergraduate students from three universities in Beijing (Beijing Forestry, China Agriculture, and Beijing Science and Technology) participated. All were native speakers of Mandarin Chinese with normal or corrected to normal vision.

Materials

Twenty target pictures with monosyllabic names were selected from Zhang and Yang's (2003) picture database. Each target was matched with four distractor types, corresponding to semantically related, orthographically related, phonologically related, and unrelated. Semantically related distractors belonged to the same semantic category as the corresponding target picture, but could not be combined with the target picture name to form a disyllabic word. In addition, each semantically related item and the name of its corresponding picture did not share a semantic radical, such as 龟(/gui1/, turtle) and 蛙(/wa1/, frog). A semantic radical refers to a feature in a character that denotes meaning. To match the degree of semantic relatedness (DSR) between a target name and its distractor, pairs were rated on a 9-point scale with 1 indicating that the characters were totally different in meaning and 9 indicating the characters were semantically identical. The mean value was 6.11 ($SD = 0.66$) with a range between 4.90 and 7.33. Pair-wise comparisons found no difference in DSR between characters (all ts < 1). Semantically related distractors were orthographically and phonologically dissimilar to the target. Orthographically related distractors were from Han's (1993) feature information database of characters. Characters were chosen if they shared orthographic structure and one component of the character of the corresponding target. In addition, to match degree of orthographic relatedness (DOR) between a target name and its orthographically related distractor, pairs were rated on a 9-point scale with 1 indicating characters were totally different in orthographic features and 9 indicating characters were orthographically identical. Twenty-four undergraduate students (12 male and 12 female, age ranged from 18 to 22 years old) from Beijing Forestry University participated this pretest (they did not take part in experiment reported below). Each participant completed DSR and DOR ratings. The order of DSR and DOR ratings was counterbalanced among participants. The mean value was 5.98 ($SD = 0.70$) with range of 4.86 to 7.45. Pair-wise comparisons found no difference in DOR between characters (ts < 1). Orthographically related distractors were phonologically and semantically unrelated to the target. Phonologically related distractors shared a syllable with the target but had different tone. Phonologically related distractors were orthographically and semantically unrelated to the target. Unrelated items were semantically, orthographically, and phonologically unrelated to the picture names. Distractors in each condition were matched for number of strokes and written frequency based on normative information reported in the Beijing Institute of Language (1986). Pair-wise comparisons revealed that mean stroke number and mean frequencies of items across conditions were not significantly different. An example from each condition with mean values for frequency and stroke number for targets and distractors is in Table 1. All items are reported in Appendix A.

Design

The design included a within-subjects factor with four levels (distractor type) and a between-subjects factor with seven levels: −300 ms, −200 ms, −100 ms, 0 ms, 100 ms, 200 ms, 300 ms (called SOA). Each participant saw the 20 target pictures four times i.e., 80 trials. The order of trials was pseudorandom to prevent a target from repeating across two trials. Experimental trials were preceded by eight practice trials. The experiment was run using E-Prime Professional Software (Beta 4.0). Stimuli presentation and data collection were performed using a Pentium PC with a high-resolution monitor (800 × 600). Naming responses were recorded by microphone, connected with the computer via a PST Serial Response Box. Reaction times were determined by voice key.

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 their task was to name pictures. First,

TABLE 1
Example stimuli with mean number of strokes and written word frequency (*SD*) (per million).

		Distractor type			
		Semantically related	*Orthographically related*	*Phonologically related*	*Unrelated*
	床	枕	庆	创	伸
Meaning	bed	pillow	to celebrate	to create	to extend
Phonetics	/chuang2/	/zhen3/	/qing4/	/chuang4/	/shen1/
Word	375	376	134	430	277
frequency	(407)	(615)	(200)	(756)	(332)
Number strokes	10.60	9.00	10.20	9.90	10.55

participants were trained to criterion with the set of experimental pictures by viewing each target for 3000 ms with the picture name printed below each picture. Then, each experimental block was administered with 8 practice trials and 80 experimental trials. Each participant received only one block in one SOA. 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 (either the distractor or the target) appeared, then the second item appeared after a pre-specified SOA. The distractor word would then be replaced by a cross (+) after presentation for 300 ms. Display duration for each target was 600 ms. A blank screen appeared until the participant made a vocal response. Participants were asked to name the target aloud as quickly and accurately as possible. Following each response, the experimenter judged the response as correct or not. The interval between two trials was 2000 ms.

RESULTS

Data from 11 participants were discarded because their percentage of incorrect responses and other responses (including trials of latencies longer than 1500 ms or shorter than 200 ms) was greater than 10%. After that, the number of participants was 15 at 0-ms SOA and 14 in all other SOA conditions. In addition, data from incorrect responses, naming latencies longer than 1,500 ms or shorter than 200 ms, and those deviating by more than three standard deviations from cell means were removed from all analyses. The above-mentioned criteria accounted for 1.6%, 0.1%, and 1.1% of the data respectively. Remaining data were used to calculate means. Mean naming latencies and error percentages for each condition are shown in Table 2.

TABLE 2
Participant reaction times means (ms) per condition with error percentage (%).

	SOA													
	−300		*−200*		*−100*		*0*		*100*		*200*		*300*	
Distractor type	*M*	*%*	*M*	*%*	*M*	*%*	*M*	*%*	*M*	*%*	*M*	*%*	*M*	*%*
Semantic	628	1.4	606	1.8	603*	1.4	627*	1.0	554	2.1	523	2.8	564	0.3
Orthographic	592	0.4	583	1.4	567*	1.1	577*	0.7	551*	0.4	530	0.6	565	1.0
Phonological	590	0.7	584	1.8	594	1.1	607	1.0	544*	1.4	540	1.9	574	0.3
Unrelated	604	2.1	587	0.5	583	3.6	611	0.7	567	0.7	526	1.6	580	0.7

*$p < .05$.

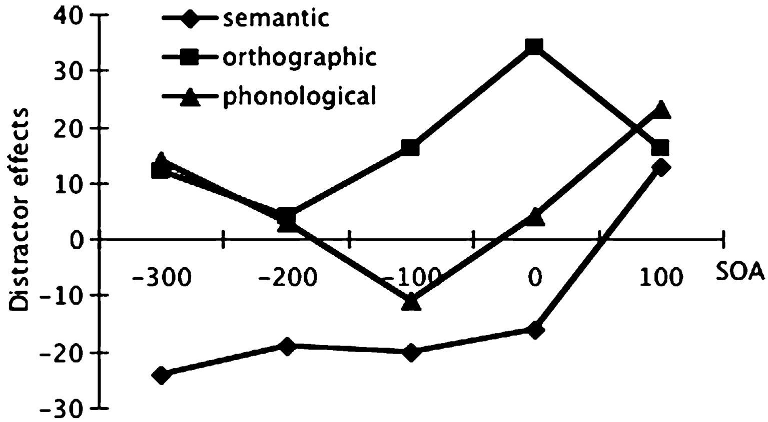

Figure 2. The effects of semantic inhibition, phonological facilitation, and orthographic facilitation.

ANOVA (F_1) was carried out with distractor condition as a within-subjects variable and SOA as a between-subjects variable. The corresponding item analysis (F_2) was also performed. A significant SOA condition effect was found, $F_1(6, 92) = 2.26$, $p < .05$; $F_2(6, 133) = 9.88$, $p < .001$. The main effect of distractor type was also significant, $F_1(3, 276) = 18.61$, $p < .001$; $F_2(3, 399) = 6.59$, $p < .001$. The interaction between SOA and distractor condition was significant, $F_1(18, 276) = 5.64$, $p < .001$, $F_2(18, 399) = 2.24$, $p < .05$. Newman–Keuls pair-wise comparison was used to compare the unrelated condition with all other conditions from an SOA of −300 ms to 100 ms. Results showed an effect of semantic inhibition from −300 ms to 0 ms (all ps < .05), orthographic facilitation from −100 ms to 100 ms (all ps < .05) and phonological facilitation from 100 ms ($p < .05$). Figure 2 shows the effects of semantic inhibition, phonological facilitation, and orthographic facilitation. No other comparisons reached significance (all ps > .05). Similar analyses were carried out on errors. Effects of SOA, distractor type, and the interaction between these variables were not significant. Therefore, no speed-accuracy trade-off effects are apparent.

DISCUSSION

We found an orthographic facilitation effect in the time window between −100 ms to 100 ms and a phonological facilitation effect at 100 ms. As expected orthographic facilitation occurred before phonological facilitation. The data therefore show that orthographic facilitation is temporally distinct from phonological facilitation which is compatible with the assumption that orthographic and phonological facilitation effects can arise at different levels of processing in Chinese spoken word production (Weekes et al., 2002). Moreover, we would highlight the fact that orthographic condition used orthographically similar but phonologically different distractors and the phonological condition contained phonologically similar but orthographically different distractors. So, compared with effects of phonological facilitation reported in English and Dutch, our results revealed relatively pure effects of phonological facilitation.

We also found evidence of orthographic and phonological facilitation at an SOA of 100 ms showing that facilitation can occur at a common level of processing. This finding is compatible with the results of Bi et al. (2008) although we note that their effects were observed at an SOA of 0 ms. Correlated effects of phonological facilitation and semantic inhibition are consistent with studies in Dutch and English (Damian & Martin, 1999; Glaser & Düngelhoff, 1984; Jescheniak & Schriefers, 1998; Lupker, 1982; Meyer & Schriefers, 1991; Rayner & Springer, 1986; Starreveld, 2000; Starreveld & La Heij, 1995, 1996).

Our data challenge the name retrieval view of phonological facilitation effects i.e., the locus of the effect on picture naming results from retrieval of orthographic codes. This has implications for the name retrieval view of phonological facilitation on picture naming in English and Dutch since phonological facilitation, although certainly co-incident with orthographic facilitation may not necessarily result from overlap between orthography and phonology in alphabetic languages. Instead, phonological facilitation on picture naming could result from priming of phonological representations such as those that are assumed in Figure 1. Our results suggest that models of spoken production need to accommodate pure phonological facilitation effects at that level.

Our results are also compatible with the claim that picture name facilitation can be generated by orthographic similarity between the distractor and target. As orthographic similarity between a distractor and target facilitates picture naming, the outstanding question is where to locate these effects in models of speech production. One possibility is to assume that the similarity between a distractor and a target activates target orthography at the level of orthographic input (as depicted in Figure 1), which then activates target phonology via the direct pathway (right side of Figure 1). As orthographic information is retrieved earlier than phonological codes during written word processing the retrieval of a word form (which perhaps occurs at around the 100-ms SOA) serves to bind orthography and phonology. However, it is not clear from this account why orthographic distractors would activate target phonology at an earlier stage of processing than a phonological distractor. If shared orthography has an impact on target picture naming at the level of name retrieval only and this occurs via the direct pathway then there is no reason to expect differences between the time course of independent orthographic and phonological facilitation effects.

As we found evidence of temporally distinct facilitation effects, we can reject this account of (relatively early) orthographic facilitation effects observed here.

An alternative possibility is that shared orthography activates the target concept via the lexical semantic pathway thus allowing rapid retrieval of the target name. This account actually predicts an overlap between orthographic facilitation and semantic inhibition as orthographic facilitation is assumed to occur via the activation of conceptual representations. This is exactly the pattern that we observed at −100 and 0 ms, i.e., orthographic facilitation together with semantic inhibition. The results therefore suggest a course of orthographic facilitation that proceeds from orthography to conceptual representations and then to phonological output (via the lexical-semantic pathway). Note also that we did not observe phonological facilitation co-incident with semantic inhibition.

Although our results point to a clear dissociation in the temporal course of orthographic and phonological facilitation effects, we also found evidence of overlap in facilitation effects at an SOA of 100 ms. These results suggest a common level of processing in word production that occurs with a relatively late onset. Hoshino and Kroll (2007) suggested that lexical codes maybe connected bi-directionally in Japanese speech processing allowing orthographic representations to modulate phonological processing in production. All computational models of oral reading in English assume bi-directional links between orthography and phonology, which then allow feedback effects (phonology to orthography) during lexical processing (see Coltheart et al., 2001 for an implementation). Although current computational models of oral reading in Chinese do not assume feedback between orthography and phonology (see for example Perfetti et al., 2005), the framework in Figure 1 allows feedback effects. Unlike alphabetic languages however we do not expect early, automatic feedback from phonology to orthography due to decoupling of orthography and phonology. Instead, we expect feedback at later SOAs in Chinese. Note that, although orthographic and phonological facilitation may be co-active at this later stage of word production, we do not mean to imply that these two levels of processing necessarily interact.

Orthographic facilitation effects may be unique to Chinese and other languages that contain words that rely on lexical-semantic reading processes e.g., irregular words in English. A few behavioural studies show that orthographic information is activated automatically at an early stage of word reading if Chinese words are presented visually (Wong & Chen, 1999). In the Mainland, when characters are learned in elementary school teachers ask students to write characters first, then to learn the corresponding phonetic pinyin. Because there is an emphasis on learning unique orthographic combinations, orthographic information may be activated automatically in lexical processing. It may not be surprising therefore to observe orthographic facilitation if orthographic awareness is a critical component of lexical processing in Chinese. It is still an open question how much orthography contributes to the facilitation effect on picture naming in languages using an alphabetic script. One methodological implication of the present findings is however that items with inconsistent spellings in English, e.g., '*bear*', may introduce an extra level of noise into the speech production system during the picture-word task and hence need to be controlled. One way to test this hypothesis in English would be to present items with orthographically ambiguous spelling patterns (rimes), such as the word fear superimposed on a picture of a pear.

In sum the present study found orthographic and phonological facilitation effects on picture naming at different SOAs. Of greatest importance, orthographic facilitation was independent of phonological facilitation at the earliest stages of word recognition (−100 ms). These temporally distinct effects challenge the name retrieval view of facilitation effects in word production. The results suggest that models of word production should consider effects of orthography on picture naming, at least in Chinese.

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APPENDIX A
Stimuli used in experiment

Picture name	Semantic Distractor	Orthographic Distractor	Phonological Distractor	Unrelated Distractor
蛇/she2/, snake (92)	虎 /hu3/, tiger (241)	舵 /duo4/, helm (16)	社 /she4/, society (2488)	寄 /ji4/, to post (118)
狗 /gou3/, dog (245)	马 /ma3/, horse (1056)	拘 /ju1/, arrest (39)	垢 /gou4/, dirty (5)	帛 /bo2/, silk (6)
鹰 /ying1/, owl (40)	雕 /diao1/, vulture (58)	腐 /fu3/, rotten (142)	影/ying3/, shadow (952)	璧 /bi4/, jade (5)
针/zhen1/, needle (378)	布 /bu4/, cloth (812)	叶 /ye4/, leaf (374)	枕 /zhen3/, pillow (46)	临/lin2/, approach (255)
脚 /jiao3/, foot (746)	眼 /yan3/, eye (2385)	卿/qing1/, general (6)	焦 /jiao1/, focus (118)	离 /li2/, leave (881)
床 /chuang2/, bed (454)	枕 /zhen3/, pillow (46)	庆 /qing4/, celebration (71)	创 /chuang4/, creation (506)	伸/shen1/, to extend (329)
树 /shu4/, tree (937)	藤 /teng2/, vine (28)	椒 /jiao1/, pepper (15)	殊/shu1/, different (105)	查 /cha2/, look up (480)
花 /hua1/, flower (1574)	叶 /ye4/, leaf (374)	苻 /fu4/, symbol (1)	划 /hua2/, pull (553)	北 /bei3/, north (780)
剑 /jian4/, sword (89)	棍 /gun4/, stick (91)	敛 /lian3/, to restrain (13)	茧 /jian3/, cocoon (20)	茶 /cha2/, tea (253)
鞋 /xie2/, shoe (295)	裤 /ku4/, trousers (94)	蛙 /wa1/, frog (63)	谢 /xie2/, thank (317)	墨 /mo4/, Chinese ink (91)
糖 /tang2/, candy (127)	酒 /jiu3/, wine (65)	粹 /cui4/, pure (20)	躺 /tang3/, to lie (205)	薪 /xin1/, salary (29)
梨 /li2/, pear (23)	枣 /zao3/, Chinese date (25)	染 /ran3/, dye (238)	理 /li3/, theory (2570)	善 /shan4/, kind (241)
鼓 /gu3/, drum (331)	琴 /qin2/, violin (79)	彭 /peng2/, surname (1)	辜 /gu1/, crime\ (13)	零 /ling2/, zero (261)
锯 /ju4/, saw (24)	斧 /fu3/, axe (53)	镇 /zhen4/, town (251)	菊 /ju2/, chrysanthemum (17)	崩 /beng1/, collapse (42)
碗 /wan3/, bowl (248)	叉 /cha4/, fork (28)	碱 /jian3/, alkali (56)	顽 /wan2/, naughty (78)	幕 /mu4/, curtain (179)
猪 /zhu1/, pig (93)	羊 /yang2/, goat (239)	赌 /du3/, to bet (34)	柱 /zhu4/, pillar (95)	晨 /chen2/, morning) (181)
鹿 /lu4/, deer (18)	狼 /lang2/, wolf (105)	席 /xi2/, mat (837)	颅 /lu2/, skull (6)	绯 /fei1/, red (8)
船 /chuan2/, boat (1016)	筏 /fa2/, raft (1)	铅 /qian1/, lead (83)	串/chuan4/, bunch (116)	逸 /yi4/, leisure (18)
枪 /qiang1/, gun (469)	炮 /pao4/, cannon (256)	构 /gou1/, to construct (334)	墙 /qiang2/, wall (283)	昏 /hun1/, dim (147)
云 /yun2/, cloud (298)	风 /feng1/, wind (1474)	亏/kui1/, deficient (90)	允 /yun3/, to allow (110)	半 /ban4/, half (1244)

Note: The number in parentheses represents written word frequency (per million) of each word.