A psycholinguistic investigation of speech production in Mandarin Chinese

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Chapter 3

The time course of speech production revisited: No early orthographic effect, even in Mandarin Chinese[4]

[4] A version of this chapter has been submitted for publication as Man Wang, Yiya Chen, Minghu Jiang, & Niels O. Schiller (submitted). The time course of speech production revisted: No early orthographic effect, even in Mandarin Chinese.

Abstract

Most psycholinguistic models of speech production agree on an earlier semantic processing stage and a later word-form encoding stage. Using a language with a logographic script, Mandarin Chinese, Zhang and Weekes (2009) reported an early effect of orthography in a picture-word-interference study and suggested that orthography can affect speech production via a lexical-semantic pathway at an early stage. This early orthographic effect without co-occurrence of phonological effect, however, was not replicated (Zhao, La Heij, & Schiller, 2012). The present study aimed to shed light on the contradictory results and further tap into the potential interaction and time course of orthography and semantic processing. Experiment 1 re-investigated the orthographic effect on picture naming. The results demonstrated a semantic interference effect at negative SOAs while orthographic relatedness facilitated picture naming at a positive SOA. No interaction between semantic and orthographic relatedness was found. The results thus replicated Zhao et al. (2012) with a late effect of orthography. Given that in both Experiment 1 and previous studies, complex Chinese characters were used as stimuli with sub-parts indicating either the sound or the meaning of the whole characters, the different results with respect to Zhang and Weekes (2009) could have resulted from varying degrees of overlap between orthographic and either phonological or semantic information. Experiment 2 therefore used simplex Chinese characters so as to clearly dissociate the semantic and phonological representations from orthography. The results revealed an orthographic effect but only at a similar point in time as the phonological effect, both of which followed the semantic effect. Taken together, our results raise doubts about the role of orthography at the conceptual level of speech planning and lend further support to a two-step model of speech production.

3.1 Introduction

An important issue in psycholinguistic research is the extent to which psycholinguistic models are capable of accounting for cross-linguistic differences. Models of speech production generally recognize several major processing stages: conceptualization, lemma retrieval, word-form encoding and articulation (e.g., Caramazza, 1997; Levelt, 1992, 1993; Dell & O'Seaghdha, 1991, 1992; the WEAVER++ model, Levelt, Roelofs, & Meyer, 1999a, b; Roelofs, 1992; Roelofs & Meyer, 1998). Previous studies have reported that orthographic relatedness modulates the speech production response latencies (Lupker, 1982; Posnansky & Rayner 1978; Underwood & Briggs, 1984). However, models of speech production have been mainly based on evidence from West Germanic languages, where orthographic and phonological forms are less clearly distinguished. For instance, the WEAVER++ model postulates a modality-neutral lemma representation where orthography is not specified (Levelt, Roelofs, & Meyer, 1999a, b; Roelofs, 1992; Roelofs & Meyer, 1998). Alternatively, the Independent Network model (Caramazza, 1997; Rapp & Caramazza, 2002) postulates a modality-specific representation in language production with the semantic representation activating the phonological representation of the lexicon in speech production and orthographic representation in written word production. In other words, the Independent Network model recognizes the role of the orthographic representation but posits that it only affects written word production.

It is difficult to tease apart orthography and phonology in languages with an alphabetic script because the correspondence between grapheme and phoneme is relatively transparent with some showing very consistent mapping (as in Serbo-Croatian) but others relatively less consistent mapping (as in English) (Katz & Frost, 1992). By contrast, languages with a logographic script show a highly arbitrary grapheme-to-phoneme correspondence. Take Mandarin

Chinese as an example; the basic unit of the writing system is a logographic character, and one character usually corresponds to a syllable. The number of possible syllables in Mandarin Chinese is limited, i.e. about 400 syllables excluding lexical tones or about 1,300 syllables including tones (Duanmu, 2002). As a consequence, there is a large number of homophones, with the result that orthography plays a crucial role in distinguishing homophones. It is therefore possible that in languages with a logographic script such as Mandarin Chinese, orthography plays a different role in speech production compared to languages with an alphabetic script.

Attempts to address the separate roles of orthography and phonology in speech production have been made in English (Damian & Bowers, 2009; Lupker, 1982; Posnansky & Rayner, 1978) using the picture-word interference paradigm (e.g., Lupker, 1979; Rosinski, Golinkoff, & Kukish, 1975). In this paradigm, participants are asked to name pictures while ignoring superimposed distractor words. It is found that distractor words that belong to the same semantic category as the target interfere with picture naming and phonologically-related distractors facilitate picture naming (e.g., Starreveld, 2000; Starreveld & La Heij, 1995, 1996; see Glaser, 1992; MacLeod, 1991 for a review of the paradigm). When the distractors are both orthographically and phonologically related to the picture name, the facilitation effect is stronger compared to pure phonological relatedness (e.g., Lupker, 1982; Posnansky & Rayner 1978; Underwood & Briggs, 1984). For instance, naming the picture of a *chair* was faster with the distractor *air* (55 ms) or *bear* (23 ms), compared to an unrelated condition, from which the facilitation effect size was derived (32 ms) and attributed to orthographic overlap (Lupker, 1982). However, Damian and Bowers (2009) found that 'extra' orthography alone did not modulate the facilitation effect when distractors were presented in the auditory format instead of the visual modality. Therefore, the presence of a pure orthographic effect in speech production has remained unclear.

Two factors may have contributed to the discrepancy in the results of the studies based on English stimuli. One factor is the limited number of word pairs that can dissociate orthography and phonology in English (e.g. *bear – year*). The other factor is that the role of orthography was often not examined independently but rather tested by a subtraction approach (the effect of phonological and orthographic relatedness minus the effect of phonological relatedness; e.g., Lupker, 1982; Posnansky & Rayner 1978; Underwood & Briggs, 1984). Damian and Bowers (2009) pointed out that one of the limitations of using English words as stimuli is that the distractors in the orthographically unrelated condition were only orthographically "less similar". Consequently, this might have "underestimated the potential contribution of spelling" (Damian & Bowers, 2009, p. 595).

Mandarin Chinese provides an ideal testing ground to tease apart the role of orthography and phonology in speech production. As we mentioned earlier, it has a logographic writing system that can easily dissociate phonology and orthography. Each syllable in Mandarin Chinese contains segmental information and a lexical tone, and is represented by a single character that comprises one or more sub-elements, known as 'radicals'. A semantic radical is a sub-element of a Chinese character that conveys semantic information about the character, while a phonetic radical conveys phonological information about the character. For example, 锤 (chui2, 'hammer') (here *chui* is the 'pinyin' transcription of the Mandarin syllable, and *2* indicates Lexical Tone 2) is a complex character where the left part is a semantic radical 钅 indicating that it is related to metal, and the right part is the phonetic radical 垂 (chui2, 'suspend') indicating the sound of the character 锤 (chui2, 'hammer'). Some characters, however, contain only one element (henceforth 'simplex' characters). For example, 羊 (yang2, 'sheep') is a simplex character which cannot be decomposed into sub-parts. It can be seen, then, that Chinese characters may overlap in phonology but not in orthography, and vice versa. For example, simplex 羊 (yang2, 'sheep') and 央 (yang1, 'center') are only phonologically related (i.e. overlapping at the segmental level *yang* although differing in lexical tones), while 羊 (yang2, 'sheep') and 半 (ban4, 'half') are orthographically related but have no phonological overlap (i.e. neither in segment nor in tone).

Independent orthographic and phonological facilitation effects have been reported in studies using Mandarin Chinese stimuli (Bi, Xu, & Caramazza, 2009; Zhang, Chen, Weekes, & Yang, 2009; Zhang & Weekes, 2009; Zhao, La Heij, & Schiller, 2012). Nevertheless, studies that have manipulated the stimulus onset asynchrony (SOA) have yielded mixed results regarding the temporal locus of the orthographic effect (Zhang et al., 2009; Zhang & Weekes, 2009; Zhao et al., 2012). Using the picture-word interference paradigm, Zhang and colleagues (Zhang et al., 2009; Zhang & Weekes, 2009) reported orthographic effects with the negative SOAs (-150 ms and -100 ms) without co-occurrence of any phonological effect, which led them to claim that sharing orthography might activate the target concept via the lexical-semantic pathway (Link A in Figure 3.1) and facilitate the target name retrieval at an earlier stage compared to the phonological effect. However, the results were not replicated by Zhao et al. (2012). Instead, their results demonstrated that orthographically and phonologically related distractors both facilitated picture naming at a similar stage, i.e. the word-form encoding stage of speech production.

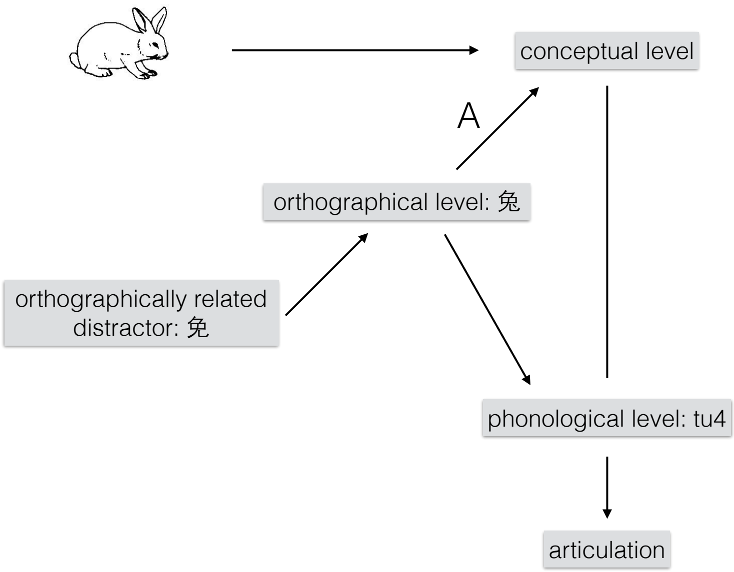

Figure 3.1 The model of overt picture naming with distractors in Chinese (adapted from Zhang & Weekes, 2009; Zhao et al., 2012).

In addition to the lack of consensus in the literature regarding the time course of the orthographic effect on picture naming, another issue that has not been explicitly addressed in the existing literature, is whether orthographically-related distractors affect speech production by interacting with the related semantic representation of the target word. The goal of Experiment 1 of the present study was therefore two-fold. First, we were interested in resolving the controversy whether orthographically-related distractors affect speech production via a lexical-semantic pathway independent of the phonological effect. Second, we were interested in whether orthographically-related distractors affect speech production by interacting with semantics. To this end, we employ a full factorial design including all four possible conditions of semantic and orthographic overlap: semantically and orthographically related, semantically related but orthographically unrelated, orthographically related but semantically unrelated, and unrelated. We use the picture-word interference paradigm with SOAs ranging from negative to positive values to cover the process before and after the activation of the target lemma respectively (see Schriefers et al., 1990; Zhang & Weekes, 2009; Zhao et al., 2012). A more refined increment (75 ms) is employed (instead of 100 ms as in Zhang & Weekes, 2009) to increase the sensitivity of detecting the hypothesized effects. If orthography facilitates speech production at the conceptual level, as claimed in Zhang and Weekes (2009), we expect an orthographic effect at negative SOAs, possibly with the same temporal locus as that of the semantic effect (Zhang & Weekes, 2009) or interacts with the semantic effect.

As we noted earlier, in Mandarin Chinese, simplex characters and complex characters have distinctive structural properties. Given that we used complex characters in Experiment 1 to test possible interactions between semantics and orthography, we also designed Experiment 2 with only simplex-character stimuli to further disentangle orthography from semantics and phonology. Such a design allows us to zoom into the orthographic effect as well as semantics and phonological effects on speech production without having to worry about the possible overlap between orthography and semantics or phonology. The time course of these effects can then be more clearly teased apart.

3.2 Experiment 1

3.2.1 Methods

3.2.1.1 Participants. Twenty native Mandarin speakers (5 male; average age = 27.4 years; SD = 2.41 years) studying in the Netherlands were paid for their participation. All participants signed a letter of informed consent, had normal or corrected-to-normal vision and none had any language impairments.

3.2.1.2 Materials and design. Twenty black-and-white line drawings from the International Picture Naming Project (Bates et al., 2003) and Snodgrass and Vanderwart (1980) databases, or drawn similarly, corresponding to complex character names in Mandarin Chinese (either monosyllabic N = 7 or disyllabic N = 13) were selected as target pictures. Each picture was presented with four types of monosyllabic distractors: a) semantically and orthographically related (S+O+); b) semantically related but orthographically unrelated (S+O-); c) orthographically related but semantically unrelated (S-O+); d) semantically and orthographically unrelated (S-O-). Ten other pictures corresponding to monosyllabic or disyllabic names were selected from the same databases to serve as fillers.

All the distractors were phonologically unrelated to the targets. The distractors in the four conditions were comparable in terms of word frequency, $F(3, 76) < 1$ (calculated with the log frequency of words in the SUBTLEX-CH database; Cai & Brysbaert, 2010) and visual complexity (number of strokes), $F(3, 76) = 1.655$, $p > .05$. Orthographic relatedness was operationalized by overlapping in one radical of the characters (e.g. 猫, mao1, 'cat' and 狗, gou3, 'dog' which overlap in the radical 犭). Fourteen native Mandarin speakers were asked to rate the semantic relatedness of word pairs with one distractor word and its corresponding target word on a 1-7 scale, with the higher score indicating stronger relatedness. The average rating scores per participant were then submitted to Wilcoxon Signed-Rank tests. The rating scores differed significantly between semantically related and unrelated word pairs, $Z = -3.9$, $p < .0001$. The semantic relatedness did not differ between S+O+ and S+O-, $Z = -1.9$, $p > .05$ or S-O+ and S-O-, $Z = -1.4$, $p > .05$.

The design included two factors: Distractor Type (S+O+, S+O-, S-O+, S-O-) and SOA (-150 ms, -75 ms, 0 ms and 75 ms). Each participant received 30 pictures × 4 Distractor Types × 4 SOAs = 480 trials in total in a pseudorandom order such that the same picture did not re-occur within three consecutive trials. The trials were blocked by SOA. The sequence of the blocks was counterbalanced across participants.

3.2.1.3 Apparatus and procedure. Before the experiment there was a familiarization and practice session. The participants were first shown all the pictures with their names underneath, and were then asked to name the pictures without their names presented. Incorrect answers were corrected.

Each trial in the experimental sessions consisted of: a fixation (300 ms); a blank screen (200 ms); the first stimulus that was either the target picture (350 by 350 pixels) or the distractor depending on the SOA (Arial Unicode MS, 48 point size); followed by the second stimulus (again either target picture or distractor). The stimuli lasted until the voice-key was triggered or a 2 s limit was exceeded, followed by another blank screen (500 ms). There was a self-paced pause between every two blocks.

The stimuli were presented using the software E-prime 2.0 and reaction times were recorded online by a voice-key connected with a PST serial response box. Incorrectly triggered voice-key responses were corrected manually using the program CheckVocal (Protopapas, 2007). Errors were firstly manually coded on-line and then double-checked based on the voice recordings.

3.2.2 Results and discussion

Errors (3.41% of all 6,400 data points; including incorrect and disfluent responses) and outliers (1.17%; shorter than 300 ms and longer than 1,300 ms) were excluded from further analysis. Error rates were very low and thus considered not informative enough for further statistical analysis. The naming latencies showed a skewed distribution and were therefore log-transformed (base 10). The log-transformed naming latencies (6,107 data points) were submitted to the mixed-effects modelling in R (version 3.1.0; R Core Team, 2014) as the dependent variable.

Table 3.1 The average naming latencies (ms) and percentage errors (in parentheses) for each condition in Experiment 1.

	Distractor type			
	Semantically related		Semantically unrelated	
SOA	Orthographically		Orthographically	
(ms)	related	unrelated	related	unrelated
-150	708 (.20)	713 (.22)	698 (.17)	692 (.19)
-75	719 (.22)	738 (.20)	712 (.19)	713 (.17)
0	744 (.13)	749 (.22)	724 (.27)	728 (.30)
75	730 (.25)	750 (.34)	725 (.16)	733 (.19)

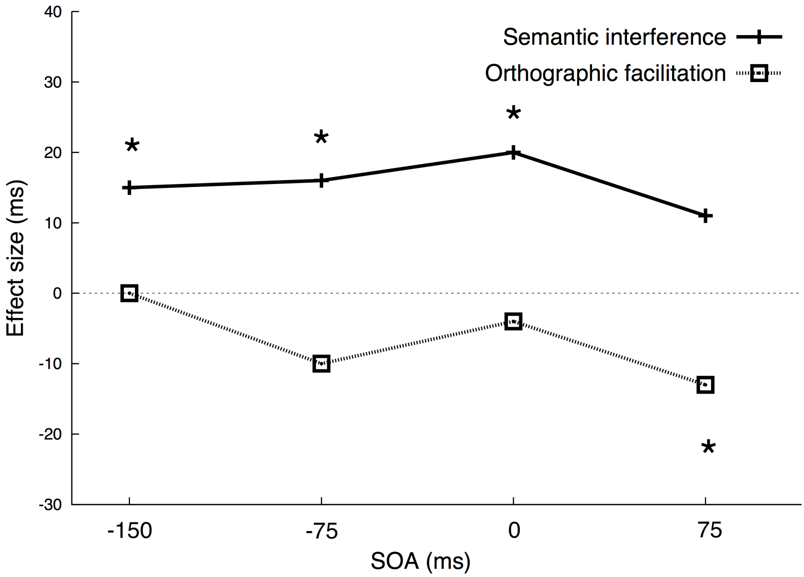

Figure 3.2 The main effects of semantic and orthographic distractors on picture naming in Experiment 1.

The initial statistical model was built using the 'lmer4' package (Bates, Maechler, Bolker, & Walker, 2014) following a maximal-model approach (Barr, Levy, Scheeper, & Tily, 2013). The initial model included three fixed predictors: semantic relatedness, orthographic relatedness and SOA, two-way interactions between distractor type (semantic and orthographic relatedness) and SOA, two random intercepts: participant and target picture, and the random slopes of fixed predictors by participant. The model failed to converge so the least variable random slope (the random slope of orthographic relatedness by participant) was removed. The interaction between orthographic relatedness and SOA was significant, $t > 1.65$ (one-tail; based on Zhang et al., 2009; Zhang & Weekes, 2009; Zhao et al., 2012). The data were then divided into four subsets per SOA. Separate models were built with semantic relatedness and orthographic relatedness as the fixed predictors, the random intercepts: the participant and target picture, and the random slopes of fixed predictors by participant. The *p*-values were obtained using the 'pbkrtest' package (Halekoh & Højsgaard, 2014).

Table 3.2 The results summary: coefficient estimates, standard errors (SE), t-values and *p*-values for the effect of distractor type in each SOA condition in Experiment 1. (significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 "." 0.1 "" 1)

SOA (ms)	Distractor Type	Coefficient Estimate	SE	*t*-Value	*p*-Value
-150	Intercept	6.5274	0.0291	224.3	
	Semantic relatedness	0.0204	0.0079	2.6	0.014*
	Orthographic relatedness	0.0015	0.0078	0.2	> 0.05
-75	Intercept	6.5598	0.0238	275.7	
	Semantic relatedness	0.0206	0.0083	2.5	0.018*
	Orthographic relatedness	-0.0136	0.0086	-1.6	> 0.05
0	Intercept	6.5764	0.0278	236.4	
	Semantic relatedness	0.0265	0.0084	3.2	0.003**
	Orthographic relatedness	-0.0099	0.0093	-1.1	> 0.05
75	Intercept	6.5827	0.0256	256.9	
	Semantic relatedness	0.0161	0.0083	1.95	> 0.05
	Orthographic relatedness	-0.0188	0.0085	-2.2	0.035*

When SOA was -150 ms, -75 ms or 0 ms, there was a significant effect of semantic interference (+15 ms, +16 ms and +20 ms respectively). Naming latencies with semantically related distractors were significantly longer than those with semantically unrelated distractors (see, e.g., La Heij, 1988; Levelt et al., 1999a; 1999b; Roelofs, 2003; but see also, e.g., Finkbeiner & Caramazza, 2006; Finkbeiner, Gollan, & Caramazza, 2006; Mahon, Costa, Peterson, Vargas,

& Caramazza, 2007; Miozzo & Caramazza, 2003 for accounts of the semantic effect). There was a significant effect of orthographic facilitation when SOA was 75 ms (difference of -13 ms). The semantic effect did not reach significance at SOA of 75 ms. The interaction between the semantic and orthographic factors did not reach significance at any SOA.

The semantic interference effect was shown at negative SOAs. This result is compatible with previous research using the picture-word interference paradigm in both languages with an alphabetic script and languages with a logographic script (e.g., Lupker, 1982; Zhang & Weekes, 2009; Zhang et al., 2009).

Critically, we did not observe an early orthographic effect or an interaction between orthographic relatedness and semantic relatedness at negative SOAs. Instead, the orthographic effect was only demonstrated with the positive SOA (i.e. 75 ms), suggesting the orthographic relatedness only affects the picture naming process after lemma retrieval, possibly at the word-form processing stage. This result did not confirm the necessity to reconstruct the speech production model regarding the orthographic effect, as suggested by Zhang and Weekes (2009).

It is worth noting that the significant semantic and orthographic effects have distinctive temporal loci without any overlap at the specified SOAs. That is, the semantic interference effect was only found at negative SOAs and orthographic facilitation at positive SOAs. This pattern is similar to the pattern of results in Schriefers et al. (1990), suggesting a two-step model of speech production that distinguishes meaning and form processing (but see e.g. Dell, Schwartz, Martin, Saffran, & Gagnon, 1997 for an interactive two-step model).

Furthermore, the effect sizes of the semantic interference and orthographic facilitation were comparable to those in Zhang and Weekes (2009) but smaller than Zhao et al. (2012). In contrast to Zhang and Weekes (2009), there was only a numerical difference between the orthographically related and the unrelated conditions at negative SOAs (-10 ms at SOA -75 ms and -4 ms at SOA 0 ms). Moreover, the size of the orthographic facilitation effect obtained at SOA 75 ms was relatively small (-13 ms) with a p-value of .035. There is a possibility that the current design is not sensitive enough to obtain a robust orthographic effect. For instance, the orthographic relatedness represented by sharing one radical (e.g. 碗, wan3, 'bowl' and 矿, kuang4, 'mine' share the radical 石, shi2, 'stone') may not be salient enough to facilitate picture naming. It has been discussed in the Chinese character literature that the characters are likely to be processed as a whole, in line with a holistic processing view (e.g., evidence from Cheng, 1981; Tzeng, Hung, Cotton, & Wang, 1979; Yu, Feng, Cao, & Li, 1990; but see evidence from Feldman & Siok, 1999; Yeh & Li, 2004 for an analytic view). Consequently, it is possible that the partial overlap is not perceptually processed individually and therefore did not produce an orthographic effect at negative SOAs.

Experiment 2 was designed to tap into the time course of the orthographic effect using simplex characters with orthographic relatedness implemented as the whole-character orthographic similarity. Another advantage of using simplex characters is that we can avoid implicit confounding effects of orthography and phonology or semantic information.

3.3 Experiment 2

3.3.1 Methods

3.3.1.1 Participants. Sixty-eight native Mandarin speakers (30 male; average age = 21.6 years; SD = 2.19 years) living in Beijing, China were paid for their participation in the experiment. All participants signed a letter of informed consent, had normal or corrected-to-normal vision and none had any language impairments.

3.3.1.2 Materials and design. Twenty target pictures were selected from the same sources as in Experiment 1. The target pictures in Experiment 2 corresponded to monosyllabic simplex names in Mandarin Chinese (i.e. written using non-decomposable, simplex characters). Each picture was presented with four different types of superimposed monosyllabic distractors: a) semantically related but orthographically and phonologically unrelated (S+O-P-); b) orthographically related but semantically and phonologically unrelated (S-O+P-); c) phonologically related but semantically and orthographically unrelated (S-O-P+); d) semantically, orthographically and phonologically unrelated (S-O-P-).

The distractors in the four conditions, as well as the names of the target pictures, were comparable in terms of word frequency, $F(4, 95) < 1$ (calculated with the log frequency of words in the SUBTLEX-CH database; Cai & Brysbaert, 2010) and visual complexity (number of strokes), $F(4, 95) = 1.421$, $p > .20$. Moreover, two separate online surveys were carried out to ensure the semantically related distractors were not orthographically related to the targets and vice versa. In each survey, 40 native speakers of Mandarin were asked to rate the semantic or orthographic relatedness of word pairs on a 1-7 scale, with the higher score indicating stronger relatedness. Rating scores were first transformed to z-scores per participant, and then submitted to the Friedman test. There were statistically significant differences in the rating scores for orthographic and semantic relatedness among the four conditions, $\chi^2(3) = 71.167$, $p < .001$ and $\chi^2(3) = 67.774$, $p < .001$, respectively. Post-hoc analyses using Wilcoxon Signed-Rank tests were conducted with Bonferroni correction. The results showed respectively that orthographically related stimuli were rated as significantly more orthographically related, and semantically related stimuli were rated as significantly more semantically related compared to the other three conditions, *p*-values < .001. Phonological relatedness was represented by overlapping the segmental information of syllable pairs (e.g., 羊, yang, 'sheep' and 央, yang, 'center'). Twenty other pictures corresponding to monosyllabic names were selected from the same databases to serve as fillers.

The design included two factors: Distractor Type and SOA (-150 ms, -75 ms, 0 ms and 75 ms) as in Experiment 1. In total, there were 16 combinations of the two factors. The 16 conditions were assigned to four groups of participants based on the Latin-square method, with 17 participants per group. In this way, each group of participants was presented with four different combinations of distractor type and SOA, and each saw all the pictures, distractor types and SOAs. In total, each participant received 160 trials (4 blocks by 40 trials).

3.3.1.3 Apparatus and procedure. The apparatus and procedure were the same as in Experiment 1.

3.3.2 Results and discussion

Following the criteria used in Experiment 1, errors (2.61% of all 5,440 data points; including incorrect and disfluent responses) and outliers (0.83%; shorter than 300 ms and longer than 1,300 ms) were excluded from further analysis. Error rates were very low and thus considered not informative enough for further statistical analysis. The naming latencies showed a skewed distribution and were therefore log-transformed. The log-transformed naming latencies (5,253 data points) were submitted to the mixed-effects modelling in R (version 3.1.0; R Core Team, 2014) as the dependent variable.

Table 3.3 The average naming latencies (ms) and percentage errors (in parentheses) for each condition in Experiment 2.

	SOA (ms)			
Distractor type	-150	-75	0	75
Semantically related	657 (.15)	656 (.29)	653 (.26)	588 (.13)
Orthographically related	610 (.17)	621 (.09)	615 (.09)	528 (.06)
Phonologically related	616 (.07)	627 (.11)	627 (.13)	523 (.17)
Unrelated	620 (.09)	632 (.13)	653 (.11)	565 (.11)

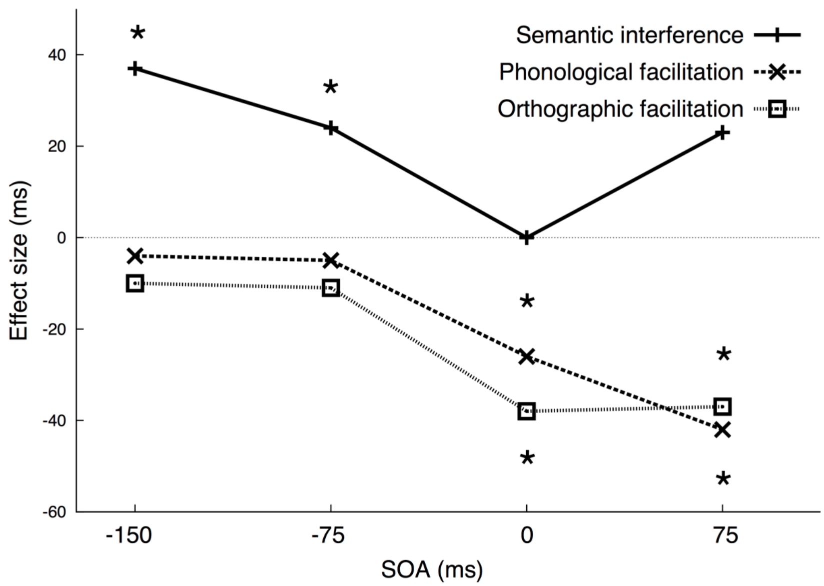

Figure 3.3 The main effects of semantic, orthographic and phonological distractors on picture naming in Experiment 2.

The initial model was built using the 'lmer4' package (Bates et al., 2014) with two fixed factors: distractor type and SOA, the interaction between distractor type and SOA, and one random intercept: target pictures. Since the experiment adopted a between-participants design, the intercept of the particpant was correlated with the fixed factors and thus was not entirely random. The model showed significant interactions between distractor type and SOA, *t*-values > 1.65 (one-tail; based on Zhang et al., 2009; Zhang & Weekes, 2009; Zhao et al., 2012). The data were then divided into four subsets per SOA. Separate models were built with the distractor type as the fixed predictor and random intercept for target picture. The adjusted *p*-values were obtained with the Bonferroni method using the 'multcomp' package (Hothorn, Bretz, & Westfall, 2008).

Table 3.4 The results summary: coefficient estimates, standard errors (SE), *t*-values and *p*-values for the effect of distractor type in each SOA condition in Experiment 2. (significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 "." 0.1 "" 1)

SOA (ms)	Distractor Type	Coefficient Estimate	SE	*t*-Value	*p*-Value
-150	Unrelated	6.41577	0.01832	350.2	
	Semantically related	0.05098	0.01334	3.8	< 0.001***
	Orthographically related	-0.01804	0.01343	-1.3	> 0.05
	Phonologically related	-0.00814	0.01326	-0.6	> 0.05
-75	Unrelated	6.43313	0.01827	352.2	
	Semantically related	0.03496	0.01370	2.6	0.032*
	Orthographically related	-0.02119	0.01351	-1.6	> 0.05
	Phonologically related	-0.00585	0.01352	-0.4	> 0.05
0	Unrelated	6.46080	0.01777	363.0	
	Semantically related	0.00097	0.01431	-0.1	> 0.05
	Orthographically related	-0.05586	0.01462	-3.9	< 0.001***
	Phonologically related	-0.03658	0.01424	-2.6	0.031*

75	Unrelated	6.30905	0.02193	287.64	
	Semantically related	0.02358	0.01919	1.2	> 0.05
	Orthographically related	-0.07703	0.01904	-4.1	< 0.001***
	Phonologically related	-0.07101	0.01911	-3.7	< 0.001***

As shown in Table 3.2, when SOA was -150 ms, there was a significant effect of semantic interference (+37 ms), *p* = .0004. Naming latencies with semantically related distractors were significantly longer than those with semantically unrelated distractors. When SOA was -75 ms, there was again a significant effect of semantic interference (+24 ms), *p* = .0321. The orthographic effect and phonological effect did not reach significance at negative SOAs. These results are in line with the results of Experiment 1.

When SOA was 0 ms, there was a significant effect of orthographic facilitation (-38 ms), *p* = .0002, and a significant effect of phonological facilitation (-26 ms), *p* = .0307. When SOA was 75 ms, there was again significant effects of orthographic facilitation (-37 ms), *p* = .0002 and phonological facilitation (-42 ms), *p* = .0007. The semantic effects did not reach significance at SOAs 0 or 75 ms.

In summary, using solely simplex characters, we did not observe an orthographic effect with negative SOAs, indicating the early orthographic effect shown in Zhang and Weekes (2009) may not be reliably obtained. Instead, both orthographic and phonological effects were found at positive SOAs, replicating results in Zhao et al. (2012). Furthermore, the effect sizes of orthographic and phonological facilitation were also found to be comparable to those in Zhao et al. (2012), i.e. 37 ms and 38 ms after excluding stimuli with phonetic radicals.

In contrast to the results of Experiment 1, at SOA 0 ms, the semantic interference effect did not reach significance in Experiment 2. The discrepancy may be attributed to the difference in distractor frequencies between Experiment 1 and 2. The distractor frequency (calculated by taking the log frequency of words in the SUBTLEX-CH database; Cai & Brysbaert, 2010) is lower in Experiment 1 (mean = 2.49) than in Experiment 2 (mean = 3.64), $p < .0001$. It has been shown that lower-frequency distractors produce stronger interference at the lexical selection stage (Miozzo & Caramazza, 2003). The difference in distractor frequency may also explain the faster average naming latencies and lower error rates in Experiment 2 than in Experiment 1, as due to the less interference during lexical selection in Experiment 2. Note that other possibilities such as differences in stimuli set and/or participant group between the two experiments may also be attributing factors.

Interestingly, when SOA was 0 ms, the orthographic effect ($p = .0002$) was stronger than the phonological effect ($p = .0307$), which is in line with previous findings in English (e.g. Lupker, 1982; Posnansky & Rayner, 1978) and Chinese (Bi et al., 2009). In the present study, the phonological relatedness in the picture-word interference paradigm was presented via orthography, by using Chinese characters. Therefore, it is likely that orthography became available earlier than phonology because phonological relatedness was represented to the speakers via an extra orthography-to-phonology transformation (i.e. phonological information activated after the perception of the characters). Bi and colleagues have tested for independent orthographic and phonological effects as well as their interactions using the picture-word interference paradigm. By using distractors with solely orthographic or phonological relatedness, the grapheme-to-phoneme route (sublexical) may be ruled out and the orthographic relatedness could possibly affect the speech production process via a lexical route (see Bi et al., 2009 for a detailed discussion).

It is worth noting that the distinctive temporal loci of the semantic, orthographic and phonological effects without any overlap in Experiment 2 were similar to the pattern of results found in Experiment 1, which has also been shown for Dutch in Schriefers et al. (1990), where the semantic interference effect was only found at negative SOAs and phonological facilitation at positive SOAs. In both experiments of the present study, the significance of semantic and orthographic effects did not overlap at any SOA. Taken together, these results suggest a two-step model of meaning and form processing during spoken word production for both languages with an alphabetic script like Dutch and languages with a logographic script like Mandarin Chinese. Although additional studies using high temporal resolution measurements such as electrophysiological studies are preferable to settle this debate, the behavioral results of this study do suggest that a general two-step model of speech production that makes distinction between meaning and form processings is sufficient.

3.4 Conclusion

With two behavioral experiments, the present study shows no early orthographic effect, even in a language with a logographic script like Mandarin Chinese where the orthography is characterized by opaque symbol-to-sound mappings. The results run counter to the proposal that orthography affects speech production at an early, conceptual level (Zhang & Weekes, 2009). Rather, the orthographic effects were found at similar temporal loci to the phonological effects, compatible with most speech production models (e.g., Dell & O'Seaghdha, 1992; Levelt et al., 1999a, b; Roelofs, 1992; Roelofs & Meyer, 1998). The results therefore lend further support to a two-step model of speech production in Mandarin Chinese, which distinguishes between meaning and form processings.