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BRIEF REPORT

Orthography influences spoken word production in blocked cyclic naming

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Abstract

Does the way a word is written influence its spoken production? Previous studies suggest that orthography is involved only when the orthographic representation is highly relevant during speaking (e.g., in reading-aloud tasks). To address this issue, we carried out two experiments using the blocked cyclic picture-naming paradigm. In both experiments, participants were asked to name pictures repeatedly in orthographically homogeneous or heterogeneous blocks. In the naming task, the written form was not shown; however, the radical of the first character overlapped between the four pictures in this block type. A facilitative orthographic effect was found when picture names shared part of their written forms, compared with the heterogeneous condition. This facilitative effect was independent of the position of orthographic overlap (i.e., the left, the lower, or the outer part of the character). These findings strongly suggest that orthography can influence speaking even when it is not highly relevant (i.e., during picture naming) and the orthographic effect is less likely to be attributed to strategic preparation.

Keywords Orthography · Spoken word production · Blocked cyclic naming · Mandarin Chinese

Whether or not word production is modality specific continues to be an unresolved issue. One highly contested area of debate related to this issue concerns the question whether orthography is automatically activated during spoken word production. Among the many influential models that have been proposed to capture the underlying mechanisms of language production, in particular, word production (e.g., Caramazza, 1997; Dell, 1990; Dell & O'Seaghdha, 1991, 1992; Levelt, 1989, 1992; Levelt et al., 1999a, 1999b; Roelofs, 1997; Roelofs & Meyer, 1998), are some that postulate a modality-neutral syntactic word representation that is linked to phonological and/or orthographic representations of words (e.g., the WEAVER++ model). However, in contrast to this position, the independent network (IN) model (Caramazza, 1997; Rapp & Caramazza, 2002) assumes a modality-specific lexical representation—that is, the phonological and orthographic representations of lexical items are independently connected to the semantic representation, and they do not link to each other at the lexical level. These models concur with respect to the activation of the semantic and the phonological representations but agree less on whether orthography is automatically activated during spoken word production.

The modality-specific account, for instance, is challenged by evidence concerning the contribution of orthography to spoken word production. This issue has mostly been investigated using the form-preparation paradigm (Meyer, 1990), where participants first learn and memorize prompt–response word pairs (e.g., *sugar–COFFEE*). They are then presented with the probes and asked to produce the corresponding response word. A facilitative effect has been reported when response words are phonologically related (e.g., *coffee*, *camel*, *cushion*) as compared with when they are unrelated (e.g., *coffee*, *scissors*, *giant*). Damian and Bowers (2003) reported that this facilitative effect in English is modulated by the consistency between phonology and orthography, that is, the effect disappeared

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when phonology and orthography were not consistent (e.g., *camel* and *kennel*). Their finding suggests an influence of orthography on production. However, this influence seems not to be present in Dutch (Meyer, 1990, 1991; Roelofs, 2006; see Schiller, 2007, using a different paradigm), French (Alario et al., 2007), Chinese (Chen et al., 2002) or Japanese (Kureta et al., 2015).

Moreover, most evidence suggests that activation of orthography in speaking is task dependent. For instance, orthographic inconsistency revealed an inhibitory effect in a reading aloud task but not in picture naming, word generation or associative naming, such as *contract, kanon, konijn* ('contract', 'cannon', 'rabbit'), compared with *contract, colbert, cadeau* ('contract', 'jacket', 'present'; examples are from Roelofs, 2006; see also Bi et al., 2009a). Using the picture–word interference paradigm, where a written distractor word is displayed simultaneously with a picture, orthographically related distractors facilitate picture naming in Mandarin Chinese (e.g., Wang et al., 2021; Zhang & Weekes, 2009; Zhang et al., 2009; Zhao et al., 2012). It has also been reported that orthographic primes with high frequency radicals matching a tip-of-the-tongue (TOT) target's radical in Chinese marginally increase TOT resolution (Chang et al., 2022). Taken together, these results suggest that orthography influences speech production when it is relevant to the task.

Nevertheless, there is also evidence showing orthographic priming effects in picture-naming tasks (i.e., no direct involvement of orthography) when participants were asked to name colored pictures using noun phrases (e.g., 蓝花瓶, *blue vase,* /lan2 hua1ping2/) when the adjective and the noun share an orthographic radical (e.g., 艹 in 蓝 and 花) in Mandarin Chinese (Qu & Damian, 2019). The authors thus claimed that the retrieval of phonological codes activates orthographic codes in spoken production in Mandarin Chinese. However, it should be noted that in Qu and Damian's (2019) stimulus materials, six out of 12 sets of noun phrases shared the same radical "木", which was manipulated as orthographic relatedness. This high percentage of related trials may have induced awareness of this issue and therefore exerted a strategic effect within participants when naming colored pictures (and consequently an orthographic effect).

In addition to the discrepancies of task effects on the role of orthography in speaking, another factor that may give rise to the controversial role of orthography in speaking is the degree of transparency in orthography-to-phonology mapping (Roelofs, 2006). In alphabetic languages, orthography often corresponds directly to phonology, and therefore the effects of phonology and orthography are often confounded. However, Chinese, a language with a nontransparent and nonalphabetic orthography, can serve as an appropriate target language to dissociate phonological and orthographic effects because it is easy to find items with only phonological or orthographic overlap. In the model proposed by Qu et al. (2016), although the semantic system activates phonology in speaking and orthography in writing, the links between phonology and orthography allow automatic activation of orthography in speaking (see Fig. 1).

Taken together, it is still unclear whether orthography is automatically activated during speaking and influences speaking. In the present study, we investigated whether orthographic overlap facilitates spoken word production even when orthographic information is not directly task relevant. To avoid any potential strategic effect with the colored picture naming paradigm (Qu & Damian, 2019) and to investigate if orthography influences bare noun naming, we employed the blocked cyclic naming paradigm. Blocked cyclic naming has mainly been used to study language production. In this paradigm, participants are requested to name a series of pictures repeatedly in cycles where targets are either homogeneous semantically, like *eye, nose, arm, shoulder*, or phonologically, like *bean, bell, boot, bowl*. A heterogeneous condition is provided by grouping together unrelated items, like *eye, desk, goat, sweater*. Participants are typically slower in naming pictures in the semantically homogeneous blocks (e.g., Belke, 2013; Belke et al., 2005; Belke & Stielow, 2013; Damian et al., 2001; Howard et al., 2006; Shao et al., 2015; Wang et al., 2018; but see Navarrete et al., 2014; Navarrete et al., 2012) and faster in the phonologically homogeneous blocks (e.g., Damian, 2003; Damian & Stadthagen-Gonzalez, 2009; but see Damian & Dumay, 2009), when compared with the heterogeneous blocks.

In Experiment 1 of the present study, target pictures were organized into homogeneous blocks—that is, the characters of the picture names are orthographically related (i.e., the left radical of the character was the same across the items within a block, e.g., 钅 in 钉子, 钱包), and heterogeneous blocks (i.e., the characters of the picture names are orthographically unrelated). By comparing the naming latencies in the two block conditions, we expected to observe faster responses in the homogeneous blocks if the orthographic contribution to spoken word production in Mandarin Chinese is indeed present and robust.

Experiment 1

Methods

Participants Thirty native speakers of Chinese (five males, mean age = 24.1 years, *SD* = 3.8 years) living in Qingdao, China, gave informed consent and participated in the experiment. All participants had normal or corrected-to-normal vision and no history of language deficits. They received 10 yuan for their participation.

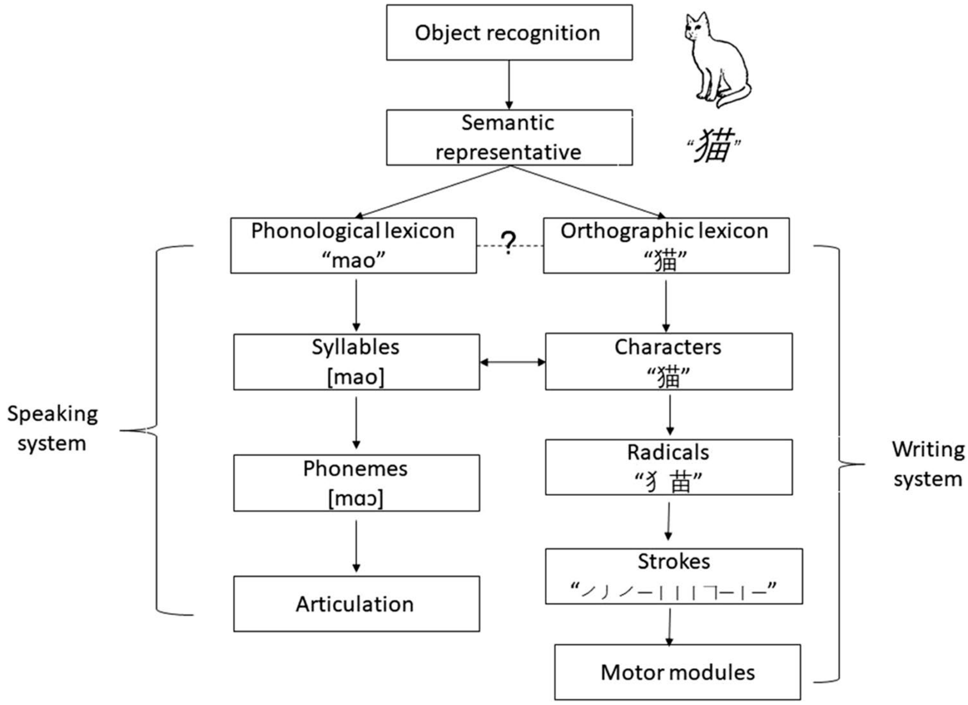

Fig. 1 Qu and Damian's model of word production system for speaking and writing in Mandarin Chinese (adapted from Qu et al., 2016)

Materials and Design Sixteen line drawings of common objects were selected from the CRL-IPNP (CRL International Picture Naming Project; Bates et al., 2000) and the standardized Snodgrass and Vanderwart picture database (Snodgras & Vanderwart, 1980), or drawn in a similar style. In addition, eight other pictures were selected from the same resource and served as target pictures in warm-up trials. All picture names were disyllabic, composed of two characters (except one trisyllabic word), and were standardized to 400 × 400 pixels and appeared in the center of the screen as black drawings on a white background.

The 16 pictures were combined to create four orthographically homogeneous blocks (see Appendix 1 Table 3), with four pictures overlapping in one radical (i.e., the left half of the first character of the target words) in each block. For instance, the first characters of the words in one block 钉子 /ding1zi0/, [nail], 钱包 /qian2bao1/, [wallet], 锦旗 /jin3qi2/, [silk banner], 钻石 /zuan4shi2/, [diamond] overlap in one radical (i.e., the left half in this case) "钅 ".

The heterogeneous blocks were created by reshuffling the sixteen pictures, in a way that the four pictures in each block were orthographically unrelated. Picture names in each block were neither phonologically nor semantically related.

The experiment had a within-participants design. In each block, all pictures were repeated four times in a cyclic manner. In total, each participant named 144 pictures (including 16 warm-ups). The pictures in each cycle were presented in a pseudo-randomized manner in such a way that the same picture did not appear in the same order in two consecutive cycles or trials. The block conditions were pseudorandomized in an ABBA manner. The stimulus lists were counterbalanced across participants.

Procedure and Apparatus Participants were seated approximately 50 cm away from a computer screen in a soundproof booth. Stimuli were presented using DMDX Version 5.2.5.1, and the reaction times (RTs, i.e., the speech onset latencies) were measured online by an HP laptop microphone and manually checked using the program CheckVocal (Protopapas, 2007) based on the participants' vocal responses.

Before the experiment started, participants were familiarized with the pictures used in the experiment. Each picture was presented once in the center of the computer screen for 2 s in a randomized order, and participants were asked to name the pictures. Participants were corrected if they used a nondominant name. On each practice trial, a fixation cross appeared in the center of the screen for 500 ms, followed by the target picture, which disappeared until the participant's response triggered the voice key (via a microphone) or a 2-s limit was exceeded, followed by a blank screen for 500 ms.

The procedure on the experimental trials was the same as for the practice trials. There was a warm-up session preceding each experimental list, consisting of two pictures which were not included in the experimental stimuli. There were self-paced pauses between blocks. The whole session lasted about 10 minutes.

Table 1 Results summary of Experiment 1: Coefficient estimates, standard errors (*SE*), *t* values and *p* values in the final model

	Coefficient estimate	*SE*	*t* value	*p* value
Intercept	6.457202	0.018945	340.85	<.0001
Orthographic relatedness	−0.017074	0.006499	−2.63	.013
Cycle	−0.000437	0.001922	−0.23	.821

Data Analysis Incorrect and disfluent responses were considered errors and excluded from the RT analysis. The error rate (3.98%) was too low to warrant analysis. RTs beyond three standard deviations from the mean (by participant) were considered outliers (1.59%) and excluded. The naming RTs showed a skewed distribution and were therefore log-transformed. The log-transformed RTs (3626 data points) were analyzed using mixed-effects modeling in R (Version 3.1.0; R Core Team, 2014) using the 'lme4' package (Bates et al., 2014). The model was built with one fixed factor (i.e., block condition [two levels: orthographically homogeneous and heterogeneous]), two random intercepts (i.e., participants and target pictures), and one control variable (i.e., presentation cycle [from 1 to 4 within a block]). By-participant and by-item random slopes of the fixed factors were also tested. The interaction between block condition and presentation cycle was tested but was not included in the final model as it did not reach significance (based on two criteria, i.e., AIC differences < 2 and *p* values > .05 in the model comparison). The final linear mixed effects model syntax is: lmer (logRT~ Block + Cycle + (1 + Block|Participant) + (1 + Block|Item)). The *p* values of the final model were obtained using the "pbkrtest" package (Halekoh & Højsgaard, 2014).

Results

Table 1 summarizes the results. First, compared with the heterogeneous blocks (mean = 656 ms, *SD* = 107 ms), RTs were significantly shorter in the orthographically homogeneous blocks (mean = 644 ms, *SD* = 98 ms). In other words, we obtained a main effect of orthographic relatedness such that the RTs were shorter by 12 ms when the orthographic characters of picture names are related than when unrelated.

By asking participants to name pictures without any cues on orthographic activation, we observed faster RTs if the orthographic forms of the picture names were related. The results of Experiment 1 showed that orthographic relatedness of the picture names, even when the orthography was not shown or cued to the participants, facilitated the picture-naming process, suggesting its involvement in spoken word production in Mandarin Chinese.

The results of Experiment 1 suggest a contribution of orthography to spoken word production in Mandarin Chinese. In view of this, it is important to determine whether this contribution results from a lexical or nonlexical processing mechanism. As stated in the experimental design, the manipulation of orthographic relatedness is realized by overlap in the left half (radical) of the character. Although there has not been clear evidence supporting a left-to-right processing order of Chinese characters in the literature, the left part is generally the initial part in writing in a "left-right" structured Chinese character and the initial part is considered more important than the noninitial part in word identification (e.g., Li, & Pollatsek, 2011; Wang et al., 2013; Zhai & Fischer-Baum, 2019). In the study of Qu & Damian (2019), the orthographic manipulation was similar (i.e., the overlapping part was confined to the initial part). One caveat with this manipulation is that the observed facilitative effect might be attributed to strategic processing. To our knowledge, it has not yet been tested whether overlap between radicals in other positions than the initial one would facilitate spoken word production. However, in languages with an alphabetic script, the phonological facilitation is restricted to the onset segmental overlap, for instance, in form-preparation and in masked onset priming, and the segmental overlap in noninitial positions often leads to interference (e.g., Breining et al., 2016; O'Seaghdha & Frazer, 2014; Schiller, 2008; but see, e.g., Foster & Davis, 1991, with nonword primes).

Thus, it is worthy to test whether the orthographic effect observed in Experiment 1 in our study is position specific. If it is limited to the left radical, this could mean that the orthographic contribution to speaking might involve a strategic component. Therefore, in Experiment 2, we altered the position of overlap of the orthographic forms to noninitial ones (i.e., the lower part in the "up–down" structured characters [e.g., 灬 in 熊猫, 黑板] and the outer part in the "in–out" structured characters [e.g., 囗 in 围裙, 国王]).

Experiment 2

Methods

Participants Thirty native speakers of Chinese (15 males, mean age = 22.0 years, *SD* = 1.7 years) living in Qingdao, China, gave informed consent and participated in the experiment. All participants had normal or corrected-to-normal

Table 2 Results summary of Experiment 2: Coefficient estimates, standard errors (*SE*), *t* values and *p* values in the final models

Presentation cycle		Coefficient estimate	*SE*	*t* value	*p* value
From 1 to 4	Intercept	6.645029	0.015102	440.01	<.0001
	Orthographic relatedness	−0.054401	0.009929	−5.48	<.0001
	Cycle	−0.044960	0.002185	−20.58	<.0001
	Orthographic Relatedness× Cycle	0.015541	0.003082	5.04	<.0001
1	Intercept	6.634347	0.019015	348.89	<.0001
	Orthographic relatedness	−0.049833	0.009586	−5.20	<.0001
2	Intercept	6.516596	0.014271	456.63	<.0001
	Orthographic relatedness	−0.007118	0.006849	−1.04	.306
3	Intercept	6.494253	0.014079	461.26	<.0001
	Orthographic relatedness	−0.009354	0.009361	−1.00	.325
4	Intercept	6.488013	0.013914	466.31	<.0001
	Orthographic relatedness	0.003965	0.008267	0.48	.635

vision and no history of language deficits. They received 10 yuan for their participation.

Materials and Design Sixteen line drawings of common objects were selected as target pictures and eight other pictures as warming-up trials, from the same resources as in Experiment 1. All picture names were disyllabic, composed of two characters (except one trisyllabic word), and were standardized to 400 × 400 pixels and appeared in the center of the screen as black drawings on a white background.

The 16 pictures were combined to create four orthographically homogeneous blocks (see Appendix 2 Table 4), with four pictures overlapping in one radical (i.e., the lower part or the outer part of the first character of the target words) in each block. For instance, the first characters of the words 盆栽 /pen2zai1/ [bonsai], 监控 /jian1kong4/ [surveillance (camera)], 盔甲 /kui1jia3/ [armor], 盒子 /he2zi0/ [box] in one block overlap in the lower half, in this case "皿".

The remainder of the experimental design was the same as in Experiment 1.

Procedure and Apparatus The procedure and apparatus were identical with those in Experiment 1.

Data Analysis Incorrect and disfluent responses were considered errors and excluded from the RT analysis. The error rate (1.67%) was too low to warrant analysis. RTs beyond three standard deviations from a participant's mean were considered outliers (1.95%) and excluded. The naming RTs showed a skewed distribution and were, therefore, log-transformed. The log-transformed RTs (3701 data points) were analyzed using mixed-effects modeling in R (Version 3.1.0; R Core Team, 2014) using the 'lme4' package (Bates et al., 2014). The model was first built and analyzed in the same way as in Experiment 1. However, the interaction between block condition and presentation cycle was significant (AIC > 2 and *p* values < .001) and therefore remained in the statistical model (linear mixed effects model syntax: lmer (logRT~ Block × Cycle + (1 + Block|Participant) + (1 + Block|Item))). The data were then divided into four subsets per presentation cycle. Separate models were built with block condition as the fixed predictor, random intercepts: participants and target pictures, and random slopes of fixed predictors by participants and by items (linear mixed effects model syntax: lmer (logRT~ Block + (1 + Block |Participant) + (1 + Block|Item))).

Results

Table 2 summarizes the results. Compared with the heterogeneous blocks (mean = 692 ms, *SD* = 95 ms), RTs were significantly shorter in the orthographically homogeneous blocks (mean = 681 ms, *SD* = 88 ms). In other words, we obtained and replicated a main effect of orthographic relatedness such that the RTs were shorter by 11 ms when the orthographic characters of picture names are related than when unrelated. However, this facilitative effect is only significant in the first presentation cycle and not in the following cycles (Cycles 2, 3 and 4).

In Experiment 2, we again observed faster RTs when the orthographic forms of the picture names were related than unrelated in a new sample. Since the position of overlap in the orthographic forms are not initial radicals in Experiment 2, we provide strong evidence for the

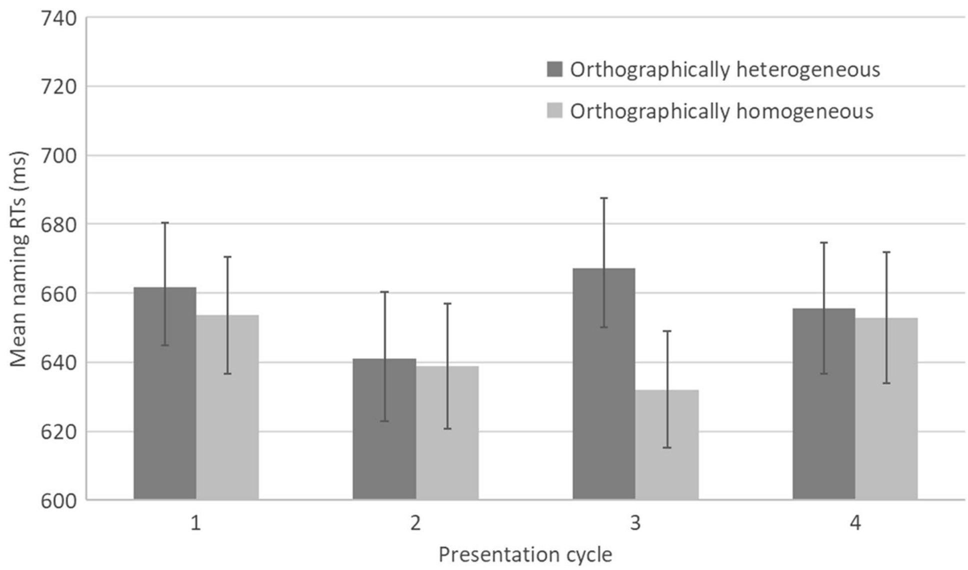

Fig. 2 Mean naming RTs (in ms) in orthographically homogeneous (dark gray) and heterogeneous (light gray) conditions in the four presentation cycles in Experiment 1. The error bars represent the positive and negative standard errors of the mean in each condition

nonstrategic nature of the orthographic facilitative effect observed in our study.

Discussion

The present study investigated the automatic activation of orthography during spoken word production using a logographic language—Mandarin Chinese. In two experiments, even without presenting the actual orthography, picture-naming latencies were shorter when stimuli were orthographically related, suggesting that orthography can influence spoken word production in Mandarin Chinese. The orthographic contribution was present with orthographic relatedness (i.e., overlapping radicals) both at the initial and noninitial positions, providing evidence for a nonstrategic nature of the facilitative effect.

In both experiments, we found an orthographic facilitation effect (12 ms in Experiment 1 and 11 ms in Experiment 2). The influence of orthography to spoken word production is consistent with previous studies (e.g., Damian & Bowers, 2003; Qu & Damian, 2019; Yoshihara et al., 2020). Different from the paradigms used in previous studies (e.g., form-preparation, Damian & Bowers, 2003; masked-priming, Yoshihara et al., 2020), we adopted the blocked cyclic naming paradigm, which only presents pictures without any visual cues leading to activation of orthography. Moreover, by showing the orthographic effect in single-word production using a bare noun naming task, which differs from the orthographic priming within adjective-noun phrases (Qu & Damian, 2019), our study lends strong support to the automatic activation of orthography during spoken word production in Mandarin Chinese.

It should be noted that although our findings suggest the automaticity of orthographic activation, we do not argue for the necessity of it in spoken word production. As one could readily point out, cases of patients with brain damage in the left hemisphere show a dissociation of phonology and orthography in language production (e.g., Caramazza & Hillis, 1991; Piras & Marangolo, 2004; Rapp & Caramazza, 2002), and thus it is apparent that speakers do not need to access orthography to speak. Naturally, children can learn to speak without any orthographic knowledge. It seems safe to state that the ability to speak is likely not severely affected even if the links between orthography and phonology (see Fig. 1) are interrupted. Interestingly, during comprehension, some found an influence of segmentation based on the nature of the script learned. For example, Japanese children segmented words initially on a syllable-by-syllable basis. However, after they have learned hiragana (a moraic script) they started segmenting Japanese using morae (Inagaki et al., 2000).

It is necessary, then, to investigate the nature of this orthographic activation. Although the used picture naming task does not include any cues on orthographic activation, one may wonder if the effect is due to strategic processing (i.e., participants were aware of the manipulation in the

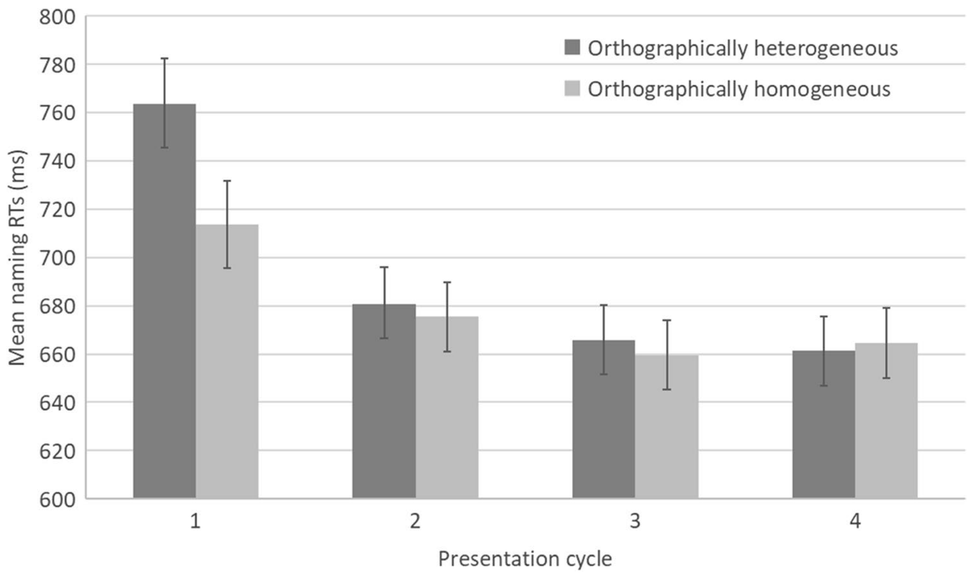

Fig. 3 Mean naming RTs (in ms) in orthographically homogeneous (dark gray) and heterogeneous (light gray) conditions in the four presentation cycles in Experiment 2. The error bars represent the positive and negative standard errors of the mean in each condition

study and consciously activated the orthographic forms of the target words). Following this assumption, the facilitative effect should not be observed in Cycle 1 where participants produced target words in organized blocks for the first time and should be more pronounced in Cycle 4 where participants had repeatedly produced the same set of words. However, in both experiments, the orthographic facilitation effect was present in the first cycle (see Figs. 2 and 3) and thus less likely to have been caused by strategic influence.

It is worth noting that in Experiment 2, there was a significant interaction between the block condition and the presentation cycle, and the orthographic facilitation was only significant in Cycle 1, whereas the interaction did not reach significance in Experiment 1. However, compared with Experiment 1, the reaction times in Experiment 2 showed a more coherent pattern.[1] Participants made fewer errors than those in Experiment 1 ($p = .002$) and naming latencies became much faster after Cycle 1. One possible account for this is that in Experiment 2 (compared with Experiment 1) stronger and more stable connections were built between the phonological lexicon and articulation after Cycle 1, which may have caused a floor effect, leaving no room for any additional contribution from orthography.

The other concern about the orthographic effect is caused by strategic processing that comes from the manipulation of orthographic relatedness via the initial radical overlap in Experiment 1. In the literature investigating phonological encoding in spoken word production, initial overlap of phonological forms usually induces a facilitative effect which might be attributed to strategic preparation. This claim is further supported by evidence showing interference or null effects with noninitial overlap in phonological forms (e.g., O'Seaghdha & Frazer, 2014; Schiller, 2008). Nevertheless, in Experiment 2 we again observed the facilitative orthographic effect with overlapping radicals at noninitial positions (i.e., the lower part or the outer part of the character).

It is important to note that the concern about the initial overlap associated with strategic processing is based on the assumed comparability between orthography and phonology. Although writing Chinese characters usually follows a left-to-right or up-to-down order, there are some complex cases. For instance, the outer radical "囗" is what starts with and also finishes with in writing characters such as "国". To our knowledge, this constitutes a novel contribution of the present study, to manipulate the overlapping position as noninitial in the investigation of orthographic processing in speech production[2] and this manipulation serves the purpose of excluding the potential strategic nature of the orthographic effect. It does not answer but raises the question how the lexicon is organized in terms of orthography. As an anonymous reviewer pointed out, in languages with a logographic script, the findings we observed in the present study may derive from a distinctive type of lexical organization where orthography is more involved and may result

[1] Based on visual inspection of the individual data in both experiments.

[2] We thank the editor and the anonymous reviewers for this suggestion.

in a different type of form-based encoding, compared with a more straightforward phonological encoding in speech production in languages with an alphabetic script. Therefore, there is also a possibility that the orthographic effect observed in our study may be attributed to the organization of the lexicon and the automatic activation of orthography may not be the only possible account. Unfortunately, compared with the extensive literature on Chinese character processing in reading (see, e.g., Cheng, 1981; Ding et al., 2004; Feldman & Siok, 1999; Qu et al., 2011; Tzeng et al., 1979; Yeh & Li, 2004; Yu et al., 1990; Zhou & Marslen-Wilson, 1999), orthography has been much less investigated in speech production (see e.g., Bi et al., 2009b; Chang et al., 2022; Wang et al., 2021; Zhang & Weekes, 2009; Zhao et al., 2012). After confirming the automatic activation of orthography in spoken word production, it would be worthwhile to establish future studies to further investigate how orthography is processed and integrated with semantics and phonology in speech production.

Where, then, does the orthographic effect arise? Qu and Damian discussed the orthographic priming in the two-word spoken phrase production in accordance with the language comprehension frameworks (e.g., Diependaele et al., 2010; Grainger & Ferrand, 1994; cf. Qu & Damian, 2019, p. 332), which integrate bidirectional links between orthography and phonology and thus allow for the possibility of orthographic effects in speech production, if applied. However, Qu and Damian did not clarify whether orthographic codes were activated via semantic or phonological codes. Although both possibilities would allow the presence of orthographic effects in speech production even when orthography is not relevant, it is worthwhile to further examine the origin of orthographic effects.

In our study, the target names within a block were neither semantically nor phonologically related, therefore confirming the possibility that the orthographic lexicon could be activated directly by the semantic lexicon and then facilitate the retrieval of phonological codes. Since there is no direct or reliable correspondence between the radical of a character and its phonological form (i.e., the overlapping radicals do not have any indication for the phonological forms), at least in our current design, the orthographic facilitation may take place at the lexical level rather than the sublexical level, which provides novel empirical evidence for the dotted link from the phonological lexicon to the orthographic lexicon in the Qu et al. (2016) model (as demonstrated in Fig. 1).

In summary, using Chinese, a language with opaque mappings between orthography and phonology, we found clear evidence for the contribution of orthography to spoken word production even when orthographic information is not relevant for production. In addition, we found that orthographic facilitation is present with orthographic overlap at both initial and noninitial writing positions. Future studies and models of spoken word production should take these results into account.

Appendix 1

Table 3.

Table 3 Stimuli in the orthographic blocks in Experiment 1

Relatedness	Target picture
氵	沙发, sofa, /sha1fa1/
	汽车, car, /qi4che1/
	海豚, dolphin, /hai3tun2/
	浴缸, bathtub, /yu4gang1/
口	吸管, straw, /xi1guan3/
	叶子, leaf, /ye4zi0/
	咖啡, coffee, /ka1fei1/
	啄木鸟, woodpecker, /zhuo2mu4niao3/
钅	钉子, nail, /ding1zi0/
	钱包, wallet, /qian2bao1/
	锦旗, silk banner, /jin3qi2/
	钻石, diamond, /zuan4shi2/
木	村庄, village, /cun1zhuang1/
	柿子, persimmon, /shi4zi0/
	枕头, pillow, /zhen3tou2/
	杠杆, lever, /gang4gan3/

Appendix 2

Table 4.

Table 4 Stimuli in the orthographic blocks in Experiment 2

Relatedness	Target picture
皿	盆栽, bonsai, /pen2zai1/
	监控, surveillance (camera), /jian1kong4/
	盔甲, armor, /kui1jia3/
	盒子, box, /he2zi0/
囗	圆规, compasses, /yuan2gui1/
	围裙, apron, /wei2qun2/
	国王, king, /guo2wang2/
	四合院, quadrangle dwelling, /si4he2yuan4/
月	背心, vest, /bei4xin1/
	膏药, plaster, /gao1yao4/
	青椒, green pepper, /qing1jiao1/
	肩膀, shoulder, /jian1bang3/
灬	熊猫, panda, /xiong2mao1/
	黑板, blackboard, /hei1ban3/
	热狗, hot dog, /re4gou3/
	蒸笼, steamer, /zheng1long2/

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Open practice statement The data for all experiments are available in the OSF repository (https://mfr.osf.io/render?url=https%3A%2F%2Fosf.io%2Fvp8sb%2Fdownload), and none of the experiments was preregistered. The materials for all experiments are available in the appendices.