American Psychological Association

Journal of Experimental Psychology: Learning, Memory, and Cognition

ISSN: 0278-7393

2020, Vol. 46, No. 8, 1570–1589
http://dx.doi.org/10.1037/xlm0000829

The Influence of Orthography on Speech Production: Evidence From Masked Priming in Word-Naming and Picture-Naming Tasks

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In a masked priming word-naming task, a facilitation due to the initial-segmental sound overlap for 2-character kanji prime–target pairs was affected by certain orthographic properties (Yoshihara, Nakayama, Verdonschot, & Hino, 2017). That is, the facilitation that was due to the initial mora overlap occurred only when the mora was the whole pronunciation of their initial kanji characters (i.e., match pairs; e.g., 化石 /**ka**-se.ki/–火力 /**ka**-rjo.ku/). When the shared initial mora was only a part of the kanji characters' readings, however, there was no facilitation (i.e., mismatch pairs; e.g., 発案 **/ha.tu**-a.N/–博物 **/ha.ku**-bu.tu/). In the present study, we used a masked priming picture-naming task to investigate whether the previous results were relevant only when the orthography of targets is visually presented. In Experiment 1, the main findings of our word-naming task were fully replicated in a picture-naming task. In Experiments 2 and 3, the absence of facilitation for the mismatch pairs were confirmed with a new set of stimuli. On the other hand, a significant facilitation was observed for the match pairs that shared the 2 initial morae (in Experiment 4), which was again consistent with the results of our word-naming study. These results suggest that the orthographic properties constrain the phonological expression of masked priming for kanji words across 2 tasks that are likely to differ in how phonology is retrieved. Specifically, we propose that orthography of a word is activated online and constrains the phonological encoding processes in these tasks.

Keywords: masked priming effect, word-naming tasks, picture-naming tasks, orthography, kanji

To produce speech from thought, several important steps are needed, such as morphological and phonological encoding. According to the most influential model of speech production, WEAVER++ (Levelt, Roelofs, & Meyer, 1999), one can build the phonological word form only after having accessed the appropriate conceptual and lemma representations. In addition, three types of information are necessary: the morphological representation, which is the metrical frame containing the number of syllables; the lexical stress pattern of the to-be prosodified word; and the phonological units, which correspond to building blocks to be inserted into the metrical frame (e.g., phonemes in English and Dutch). For example, when producing the bisyllabic word *cigar*, the construction of the phonological word form starts from the retrieval of the morpheme (*cigar*). Its phonology (/sɪga:/) is then decomposed into segmental information (/s/ /ɪ/ /g/ /a/ /:/; i.e., phonological unit) and inserted into the metrical frame, σ'σ (σ = syllable, ' = lexical stress) in an incremental fashion. As a result, the phonological word form [sɪ]['ga:] is constructed, and then the final articulatory (phonetic) part of the model will be carried out.

The basic phonological unit to fill the metrical frame was initially assumed to be the phoneme across all languages (Levelt et al., 1999). However, recent studies have demonstrated that this unit varies across languages (e.g., O'Séaghdha, Chen, & Chen, 2010; Roelofs, 2015). For instance, the phonological unit of Mandarin Chinese is now suggested to be the syllable (e.g., Chen, Chen, & Dell, 2002; Chen, O'Séaghdha, & Chen, 2016; Chen & Chen, 2013) and the unit of Japanese the mora (e.g., Kureta, Fushimi, & Tatsumi, 2006; Verdonschot et al., 2011). In line with these findings, O'Séaghdha et al. (2010) proposed the "proximate unit principle," which states that the size of the first selectable (or proximate) phonological unit below the level of the word can vary across languages.

This article was published Online First March 9, 2020.

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This research was supported in part by Japan Society for the Promotion of Science, Grant-in-Aid for Scientific Research, Grants JP16J08422 to Masahiro Yoshihara and JP17K02748 to Rinus G. Verdonschot.

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Typical Tasks Used for Investigation of the Proximate Phonological Unit

Two experimental paradigms have typically been used to investigate the size of the proximate unit in phonological encoding: (1) the form preparation (or implicit priming) paradigm and (2) the masked priming paradigm. The form preparation paradigm is often combined with the associative-cuing task (e.g., Meyer, 1990, 1991; O'Séaghdha et al., 2010). In this task, participants are first asked to memorize a small set of semantically related word pairs (e.g., *night–day*, *tint–dye*, *bread–dough*, *wet–dew*). The first and second words in each pair are called the *prompt word* (e.g., *night*) and the *response word* (e.g., *day*), respectively. The participants are then presented with a prompt word. Upon seeing the prompt word, the participants are instructed to produce the correct response word as quickly and accurately as possible. In one condition (called the *homogeneous context*), all response words within a set share the same initial segment (e.g., *day*, *dye*, *dough*, *dew*). In the other condition (called the *heterogeneous context*), the response words have different initial segments (e.g., *day*, *pea*, *rye*, *sow*). Response words are produced significantly faster in the homogeneous context than in the heterogeneous context, and this facilitation effect is called the *form preparation effect* (or *form-related priming effect*). Then, the minimum size of shared phonology that elicits this facilitation effect is taken to reflect the basic phonological unit of the language (e.g., Chen et al., 2002; Chen & Chen, 2013, 2015; Kureta et al., 2006; Meyer, 1990, 1991; O'Séaghdha et al., 2010; Roelofs, 1996, 2006b; Roelofs & Meyer, 1998).

The masked priming paradigm, another paradigm that has often been used to examine the phonological unit, is normally combined with a word-naming task. In this task, participants are asked to read aloud a visually presented target word as quickly and accurately as possible. The target word is preceded by a brief presentation of a masked prime (e.g., 50 ms), which either shares the initial sound with the target or not (e.g., *belly–BREAK* vs. *merry–BREAK*). Using English, Forster and Davis (1991) showed that naming responses were significantly faster when the target and the prime shared an initial phoneme than when they did not (i.e., the masked onset priming effect [MOPE]). The masked priming effects for the prime–target pairs sharing the initial sound have also been reported in many other alphabetic languages, such as Dutch (e.g., Schiller, 2004, 2007) and Spanish (e.g., Dimitropoulou, Duñabeitia, & Carreiras, 2010). Furthermore, similar effects have been reported in nonalphabetic languages such as Chinese (e.g., Chen, Lin, & Ferrand, 2003; Chen et al., 2016; You, Zhang, & Verdonschot, 2012) and Japanese (e.g., Verdonschot et al., 2011), although the "initial sound" necessary to observe the effect was not the phoneme for these languages, as is discussed subsequently. Nevertheless, the important point here is that, as with the form preparation effects, the minimum size of phonological overlap between the prime and the target necessary to observe a significant masked priming effect has been taken to reflect the basic phonological unit of the language.

In all, the results observed in both the form preparation paradigm with an associative-cuing task and the masked priming paradigm with a word-naming task have provided converging evidence for a specific size of the phonological unit used in the phonological encoding processes of a language. As mentioned earlier, in English, a significant form preparation effect was observed when the response words shared an initial phoneme (e.g., *day*, *dye*, *dough*, *dew*; O'Séaghdha et al., 2010), and a significant masked priming effect was also observed when the prime–target pair shared an initial phoneme (e.g., *belly–BREAK* vs. *merry–BREAK*; Forster & Davis, 1991). These results consistently indicate that the phonological unit of English is the phoneme. Similarly, previous literature suggested that the phonological unit of Mandarin Chinese is a syllable. A significant form preparation effect was observed when response words shared an initial atonal syllable (e.g., 飛機 /fei1ji1/ *airplane*, 肥胖 fei2pang4/ *fat*, 翡翠 /fei3cui4/ *jade*, 肺癌 /fei4yan2/ *lung cancer*), but not when the words shared an initial phoneme (e.g., 答應 /da1ying4/ *promise*, 德國 /de2guo2/ *Germany*, 賭博 /du3buo2/ *gambling* and 地獄 /di4yu4/ *hell*; Chen et al., 2002; O'Séaghdha et al., 2010). A significant masked priming effect was also observed for word pairs sharing initial atonal syllables (again, no effect was observed for pairs sharing an initial phoneme when using masked priming word-naming tasks; e.g., You et al., 2012). On the other hand, the phonological unit of Japanese is suggested to be the mora. That is, Kureta et al. (2006) found a significant form preparation effect when the response words shared an initial mora (e.g., かつら /ka.tu.ra/ *wig*, 歌舞伎 /ka-bu-ki/ *kabuki*, 鞄 /ka.ba.N/ *bag*), but no effect was found when the words shared only an initial phoneme.[1] Likewise, Verdonschot et al. (2011) observed a significant masked priming effect when the prime–target pairs shared an initial mora (e.g., スミ /su.mi/ *Chinese ink*–すし /su.si/ *sushi*) and failed to observe a significant effect when the pairs shared only an initial phoneme (e.g., せん /se.N/ *line*–すし /su.si/ *sushi*).

The Possibility of Orthographic Influence on Speech Production

As such, the literature has accumulated consistent results within each language. Recently, however, Yoshihara et al. (2017) provided experimental evidence that was difficult to reconcile with the previous results. Using the masked priming paradigm and using exclusively Japanese kanji stimuli (i.e., two-character kanji compound words), Yoshihara et al. (2017) found that a masked priming effect did not occur when the prime–target pairs merely shared their initial mora sound (contrasting earlier findings). A significant effect was instead observed when the shared initial mora sound corresponded to the whole sound of the prime's and target's initial kanji characters. Thus, mora-related priming effects were found for match pairs (e.g., 化石 /**ka**-se.ki/ *fossil*–火力 /**ka**-rjo.ku/ *heating power*), where the shared initial mora sound **/ka/** corresponded to the whole sound of the initial kanji characters of the prime (化 /**ka**/) and the target (火 /**ka**/), respectively.[2] Conversely, for mismatch pairs (e.g., 発案 /**ha.tu**-a.N/ *suggestion*–博物 /**ha.ku**-bu.tu/ *natural history*), no mora-related priming effect was observed. In the latter case, the shared

[1] When we describe morae for Japanese words, we follow the format of Hino et al. (2011), which is based on that of Tamaoka and Makioka (2004) except in three respects: (1) a period [.] is used for a moraic boundary, (2) a hyphen [-] is used for a morphemic boundary, and (3) capital letters are used instead of /R/ for a prolonged (long) vowel (e.g., /jo-sju.U/ for 予習).

[2] In the present article, we use boldface hereafter to highlight the phonology of the first character in a word. For instance, /**ka**-rjo.ku/ (火力) means that the initial mora, **/ka/**, is the whole sound of the first character (i.e., 火).

mora sound /ha/ did not correspond to the whole sound of the initial kanji characters of the prime and the target (e.g., 発 **/ha.tu/** and 博 **/ha.ku/**). Further, it is noteworthy that when these kanji words were transcribed into kana (e.g., カセキ /ka.se.ki/–かりょく /ka.rjo.ku/, ハツアン /ha.tu-a.N/–はくぶつ /ha.ku-bu.tu/), a significant masked priming effect was observed for both the match and the mismatch pairs. The significant mora-related priming effects for the kana-transcription stimuli were consistent with the results of Verdonschot et al. (2011), which also used kana stimuli and a masked priming word-naming task. The different priming patterns for the kanji and the kana stimuli indicate that orthographic properties (i.e., script types) somehow have an impact on speech production, at least when the task is to name a word aloud.

One might argue, however, that speech production is independent of orthography as the importance of the mora during phonological encoding has been repeatedly demonstrated (without clear evidence for an important role of orthography). For instance, it has been shown that masked priming effects are observed when critical stimuli have the same mora even when a script other than kana, namely, Romanized Japanese (Romaji) was used (e.g., Verdonschot et al., 2011). It is also known that speech errors most frequently occur at mora boundaries (Kubozono, 1989). In addition, O'Séaghdha (2015) has suggested that the phonological unit is stabilized around the time when children acquire their initial productive vocabulary.

The idea that orthography affects speech production also seems inconsistent with the results from the form preparation paradigm using the associative-cuing task (Kureta et al., 2006). Kureta et al. (2006) found a significant form preparation effect using stimuli consisting of both kanji and kana words (e.g., かつら **/ka**.tu.ra/, 歌舞伎 **/ka**-bu-ki/, 鞄 **/ka.ba.N/**). Because both kanji and kana words were mixed and used as stimuli, the results of Kureta et al. (2006) indicate that the speech production process is independent of the script type in which the to-be-spoken words are presented.

One might argue, however, that there is a possibility that the results in Kureta et al. (2006) do not fully reflect the underlying nature of the speech production process. This is because the form preparation effect in the associative-cuing task might reflect processing situated at the memory retrieval stage which could be affected by participants' strategies (e.g., Alario, Perre, Castel, & Ziegler, 2007; O'Séaghdha, 2015; O'Séaghdha & Frazer, 2014). In fact, Kureta, Fushimi, Sakuma, and Tatsumi (2015) have pointed out the possibility that participants strategically use script type as a response cue in this task. Using Japanese word stimuli, Kureta et al. found a phonemic preparation effect when the stimuli were presented in Romaji (e.g., *rokku*, *renga*, *raiu*), but no such effect was found when the same word stimuli were written in kana and kanji (e.g., ロック, 煉瓦, 雷雨). Kureta et al. (2015) suggested that the phonemic preparation effect they observed does not reflect the phonological unit of Japanese being phoneme. The authors argued that the phonemic effect was found as a result of their participants having become aware of the letter–phoneme overlap, which was made salient when the stimuli were presented in Romaji, and then could strategically use them when producing response words. The results of Kureta et al. (2006), therefore, leave room for the involvement of strategic effects–the presence of kana stimuli might have made participants pay extra attention to the mora-level information and such information was strategically used in the task to yield mora-based facilitation. However, as this is just speculation, it is of course possible that the results of Kureta et al. (2006) do reflect the true phonological unit of the Japanese language (i.e., mora) that was unaffected by strategic factors.

The Present Study

As such, it is still unclear whether the properties of orthography affect speech production. It is, therefore, important to investigate whether the orthographic influence on speech production is reliable and, if it is, to what extent orthography affects it. A specific question considered here is whether orthography modulates the masked priming effects in a task other than word naming. As noted, the masked priming effects were modulated by orthography in the word-naming task: Standard mora priming effects were observed in kana (Verdonschot et al., 2011; Yoshihara et al., 2017, Experiment 3), but no such priming was observed for kanji unless the shared mora corresponded to the whole sound of the initial characters of prime–target pairs. Yoshihara et al. (2017) proposed that the effects of orthography observed in the patterns of priming effects in their study could be due to a specific task demand involved in the word-naming task. In a word-naming task, a word's phonology would be strongly tied to its orthographic form, because participants are required to read aloud a word that is visually presented right in front of them, and, hence, the phonology of a word is retrieved directly from its orthography. On the other hand, the link between orthography and phonology might play a much less dominant role in other tasks such as the associative-cuing task, because the phonology of a target word must be retrieved from the concept (Roelofs, 2006b). The same would also hold for the picture-naming task in which the phonology is retrieved via the concept–lemma–lexeme route (Roelofs, 2006a). Indeed, the orthography of the stimuli has been reported to modulate performance in the word-naming task but not in the associative-cuing and picture-naming tasks in the form-preparation paradigm (e.g., Alario et al., 2007; Bi, Wei, Janssen, & Han, 2009; Roelofs, 2006b; but see Damian & Bowers, 2003). This might indicate the possibility that the nature of speech production (and how orthography influences this process) is different depending on the task demands.

In fact, Verdonschot and Kinoshita (2018) have recently suggested that the difference in the task demands (i.e., whether the task requires to directly read the target aloud) might be a key to disentangle the discrepancy. They used a phonological Stroop task in which participants must name the color of the ink in which a word (or nonword) is written. In this variant of the classical Stroop task, it has been shown in English that the color-naming responses are faster when the (non-) word has the same initial sound as the ink color than when it does not. For example, if a word such as *rat* or a nonword such as *raz* is written in red ink (i.e., the task would be to say "red"), the color-naming responses were faster for these stimuli than for the same stimuli written in green ink. As such, the color-naming responses were faster when the color name and the (non-) word stimulus shared the same onset (i.e., /r/; see Coltheart, Woollams, Kinoshita, & Perry, 1999).

Using colored Japanese kana-written stimuli, Verdonschot and Kinoshita (2018) showed that nonwords having the same initial phoneme did not speed up the color-naming responses (e.g., ぱや /pa.ya/, written in pink) but nonwords sharing the same initial mora did (e.g., ぴや /pi.ya/, written in pink). However, more important for the present discussion is that they also showed a simple mora-based facilitation for one-character kanji stimuli: The color-naming response /mi.do.ri/ *green* was faster when the kanji character's initial mora was /*mi*/ even when that mora was not the whole sound of the character (e.g., 右 /**mi.gi**/ *right*, written in green). This finding suggests that how orthography affects production might differ depending on whether the task requires to directly read visually presented words (but see Chen et al., 2016; You et al., 2012).

It is, therefore, possible that the results observed with kanji stimuli by Yoshihara et al. (2017) were task specific and arose because their participants were asked to directly read the targets aloud. If this is the case, then, Yoshihara et al.'s proposal that speech production is affected by orthography might not be generalizable to more spontaneous word production settings, where one would not heavily rely on the orthographic forms of to-be-spoken words (e.g., associative-cuing, picture-naming, and Stroop tasks).

On the other hand, one could also propose that the results in Yoshihara et al. (2017) were not limited to a word-naming task and could be replicated in more spontaneous word production settings such as a picture-naming task. This assumption is supported by Roelofs (2004), who suggested that reading aloud (e.g., a word-naming task) and speaking (e.g., a picture-naming task) are merged at the phonological encoding process. Because the masked priming effect is assumed to arise at this process (e.g., Kinoshita, 2000, 2003; Kinoshita & Woollams, 2002; Malouf & Kinoshita, 2007; but see Forster & Davis, 1991; Mousikou, Coltheart, Finkbeiner, & Saunders, 2010a; Mousikou, Coltheart, & Saunders, 2010b), it is not unreasonable to predict that the priming patterns are the same between the word-naming and picture-naming tasks.[3] Such a result would indicate that orthography affects speech production not only in the word-naming task, but also in spontaneous word production settings (e.g., a picture-naming task; e.g., Bürki, Spinelli, & Gaskell, 2012; Rastle, McCormick, Bayliss, & Davis, 2011; Zhao, Heij, & Schiller, 2012; see also Damian & Bowers, 2003 for possible evidence of orthographic influence on the associative-cuing task).

The purpose of the present study is to examine whether the task demands modulate the patterns of masked priming effects for kanji words. That is, we investigate the impact of orthographic properties on speech production in a task in which phonology must be retrieved directly from visually presented targets (i.e., the word-naming task) as well as in a task in which phonology is derived from the activation of the concepts of the to-be-produced words (i.e., the picture-naming task).[4]

Experiment 1: Masked Priming Effects in Word and Picture-Naming Tasks

In this experiment, we examined masked priming effects using two tasks: a word-naming task and a picture-naming task. The critical stimuli were two types of phonologically related kanji prime–target pairs: the match and mismatch pairs (see Yoshihara et al., 2017, Experiments 2 and 5). The match pairs shared an initial mora that constituted the whole sound of their initial kanji characters (e.g., 破産 /**ha**-sa.N/ *bankruptcy*–葉巻 /**ha**-ma.ki/ *cigar*). The mismatch pairs also shared an initial mora sound, but the shared mora was only a part of the sounds of their first kanji characters (e.g., 拍手 /**ha.ku**-sju/ *handclap*–葉巻 /**ha**-ma.ki/). In the word-naming task, participants were presented with a target word and were asked to read it aloud as quickly and accurately as possible. In the picture-naming task, participants were presented with a picture and were instructed to name it aloud as quickly and accurately as possible.

Our predictions are as follows: first, in the word-naming task, we expected to replicate the previous findings reported in Yoshihara et al. (2017). That is, although there would be a significant masked priming effect for the match pairs, no masked priming is expected for the mismatch pairs. In the picture-naming task, on the other hand, there are two possibilities. If orthographic information only matters when speech production is under the direct influence of orthography (i.e., word naming), then the masked priming effect would be observed for both the match and the mismatch pairs. Alternatively, if there is orthographic influence on the speech production processes regardless of how phonology is retrieved, then a masked priming effect should be found only for the match pairs even in a picture-naming task.

Method

Participants. Eighty-four undergraduate and graduate students from Waseda University participated in this experiment. Forty students participated in the word-naming task (age: M = 19.4 years, SD = 1.3) and 44 students participated in the picture-naming task (25 females, age: M = 20.5 years, SD = 2.0). They were paid 500 JPY (~$US4.00) in exchange for their participation. All were native Japanese speakers with normal or corrected-to-normal vision. All the experiments reported in the present study were approved by the Ethics Review Committee on Research with Human Subjects of Waseda University (Protocol 2016–021).

Stimuli. We first selected 28 two-character kanji compounds as targets (see the Appendix, Table 1A). The mean rating score of the orthographic plausibility for these targets was 4.9 on a five-point scale (1 = *not at all adequate*, 5 = *highly adequate*),

[3] Note that the locus of the masked priming effect (specifically, the MOPE found for the alphabetic languages) in the word-naming task has not been decided. Whereas Kinoshita and her colleagues suggested that the effect arises at the phonological encoding processes (e.g., Kinoshita, 2000, 2003; Kinoshita & Woollams, 2002; Malouf & Kinoshita, 2007), other researchers have postulated that the effect is originated in the phonological computation process via the nonlexical route, from the viewpoint of the dual-route theory (e.g., Forster & Davis, 1991; Mousikou et al., 2010a, 2010b). However, as discussed in Yoshihara et al. (2017), it seems difficult to explain why there is a significant priming effect for kanji words within the framework of the dual-route account because phonology of kanji is assumed to be activated via the lexical route (e.g., Feldman & Turvey, 1980; Wydell et al., 1995; but see also Kayamoto, Yamada, & Takashima, 1998). In addition, if the significant masked priming effect is observed in the picture-naming task, its locus would not be at the phonological computation as a picture target is not named via the nonlexical route (e.g., Schiller, 2007). In the present study, thus, we assume that the masked priming effect (at least for kanji words) arises at the phonological encoding process.

[4] It is difficult to conduct the associative cuing and phonological Stroop tasks using the masked priming paradigm. We thus assumed that the picture-naming task is more suitable to investigate the phonological unit of Japanese speech production in order to examine the influence of the task demands. Indeed, J.-Y. Chen et al. (2016) extended the proximate unit principle to the masked priming picture-naming task and demonstrated that this task is useful to investigate the phonological encoding.

indicating that all targets were normally written only in kanji (Amano & Kondo, 2003a). The mean word frequency count for these targets was 19.6 per million (Amano & Kondo, 2003b). The first characters of the targets always corresponded to a single mora sound (e.g., 葉巻 /**ha**-ma.ki/). For the picture-naming task, picture targets were selected based on the word targets using Google Image Search. All pictures were 300 pixels × 300 pixels colored photographic images presented in the bitmap format.

For each target word, two types of phonologically related primes were selected. One type was the match-related primes, and this prime type shared its initial mora sound with the target and the shared mora corresponded to the whole sound of the initial kanji characters (e.g., 破産 /**ha**-sa.N/–葉巻 /**ha**-ma.ki/). The other type was the mismatch-related prime. The mismatch-related prime also shared an initial mora sound with the target but the primes' initial kanji character always consisted of two morae (e.g., 拍手 /**ha.ku**-sju/–葉巻 /**ha**-ma.ki/) and, hence, the whole sound of the prime's and target's initial characters were not identical (e.g.,/**ha.ku/** vs./**ha/**). Two types of control primes were selected for these related primes, respectively: match-control and mismatch-control primes. These control and target primes had different initial morae (e.g., a match-control pair: 遺産 /**i**-sa.N/*heritage*–葉巻 /**ha**-ma.ki/; a mismatch-control pair: 着手 /**tja.ku**-sju/*commencement*–葉巻 /**ha**-ma.ki/). The match-related and match-control primes consisted of the same second kanji characters with the same pronunciation (e.g., 破産 /**ha**-sa.N/, 遺産 /**i**-sa.N/). Similarly, the second kanji characters in the mismatch-related and mismatch-control primes also consisted of the same character with the same pronunciation (e.g., 拍手 /**ha.ku**-sju/, 着手 /**tja.ku**-sju/). In addition, the second mora of our mismatch-control primes (belonging to the initial kanji character) was the same as that of the second mora of the mismatch-related prime. As a result, the second and third morae were the same for the related and control primes in both the match and mismatch conditions, so that the related and control primes differed only in the initial mora in both conditions. The four prime types were orthographically and semantically dissimilar from the paired targets.

As shown in Table 1, the four prime types (i.e., match-related, match-control, mismatch-related, and mismatch-control) were matched on the following variables: (1) the number of morae, (2) word frequency counts (Amano & Kondo, 2003b), (3) orthographic familiarity ratings (Amano & Kondo, 2003a), (4) phonological familiarity ratings (Amano & Kondo, 2003a), (5) orthographic neighborhood sizes (calculated using a database from the National Language Research Institute, 1993), (6) summed character frequencies (calculated using Amano & Kondo, 2003b), (7) the number of strokes, and (8) orthography-to-phonology consistencies (based on Hino, Miyamura, & Lupker, 2011; all Fs < 1.9).

In addition, we collected semantic relatedness ratings of our prime–target pairs from 40 participants who did not participate in Experiment 1 in order to confirm that the four word-pair types were equally semantically unrelated at the whole word level. In the semantic relatedness rating task, participants were asked to judge to what extent each of the prime–target pairs were related in meaning on a seven-point scale (1 = *not at all related*, 7 = *extremely related*). The mean ratings for the four types of prime (match-related, match-control, mismatch-related, and mismatch-control pairs) were 1.7, 1.5, 1.8, and 1.8, respectively. A two-way analysis of variance (ANOVA) revealed that the ratings were not significantly different for the four prime types (all ps $> .1$).

Based on these 112 prime–target pairs, we created four versions of the stimulus list, each consisting of 28 prime–target pairs. Within each of the stimulus lists, one fourth of the targets (i.e., seven items out of 28 targets) were paired with primes from each of the four conditions. Each participant received all the stimulus lists and, hence, each target was presented four times. Thus, each target was paired with all four primes across the stimulus lists. The order of the stimulus lists was counterbalanced across participants. Within each list, the presentation order of the prime–target pairs was randomized for each participant. In the word-naming and picture-naming tasks, the same sets of stimuli were used, except that in the picture-naming task, each word target was replaced by a colored picture denoting the word.

Apparatus and procedure. Participants were tested individually in a quiet room. The experiment was programmed using the DMDX software package (Forster & Forster, 2003). In both tasks, the experiment consisted of learning, testing, and experimental phases.

Table 1
Lexical Characteristics of Match–Related, Match–Control, Mismatch–Related, and Mismatch–Control Primes Used in Experiment 1

Lexical variable	Match prime: Related[a]	Match prime: Control[b]	Mismatch prime: Related[c]	Mismatch prime: Control[d]
Morae	3	3	3	3
Word frequency (per million)	8.2	8.4	7.3	8.4
Orthographic familiarity rating	5.6	5.6	5.6	5.6
Phonological familiarity rating	5.4	5.4	5.4	5.3
Orthographic neighborhood size	56.1	58.2	53.4	57.2
Summed character frequency	610,172	606,805	575,477	496,170
Number of strokes	18.6	19.2	17.5	19.0
Orthographic–phonological consistency index	.8	.8	.8	.8
Semantic relatedness rating	1.7	1.8	1.5	1.8

Note. All values are means. For all examples, boldface type highlights the phonology of the first character in a word.
[a] Example: 破産—葉巻; /**ha**-sa.N/–/**ha**-ma.ki/. [b] Example: 遺産—葉巻; /**i**-sa.N/–/**ha**-ma.ki/. [c] Example: 拍手—葉巻; /**ha.ku**-sju/–/**ha**-ma.ki/. [d] Example: 着手—葉巻; /**tja.ku**-sju/–/**ha**-ma.ki/.

In the learning phase, participants in the word-naming task were asked to learn the pronunciations of all the kanji word targets. Each target kanji word was presented in the center of the computer screen for 4 s. Similarly, participants in the picture-naming task were instructed to learn the correct names of the picture targets, and each target picture was presented in the center of the screen for 4 s. The correct name for each picture was presented in kanji just below the picture. The learning phase was then followed by the testing phase, in which participants were required to name aloud the target word or picture presented on the monitor, depending on the task. When the participants responded incorrectly, the experimenter corrected the errors. The testing phase was repeated twice so that no error was made by any participants during the second testing phase.

In the experimental phase, participants were instructed to name the target stimulus aloud as quickly and accurately as possible. As noted in the preceding text, as each target word–picture was presented four times, therefore each participant was shown all prime–target pairs.

In both tasks, each trial started with a 50-ms 400 Hz beep signal. After the signal, a forward mask (i.e., ######) was presented in the center of the CRT monitor for 1,000 ms. Immediately after the forward mask, a word prime was presented for 33 ms, which was then replaced by the target stimulus. The target remained on the screen until a response was made or 2,000 ms had elapsed. Word primes and targets were presented in 12-pt. MS-Mincho font (1.5 cm × 2.5 cm in size). Picture targets were 11 cm × 11 cm in size. Naming latency was measured from the onset of the target presentation to the onset of the vocal response. Prior to the experimental trials, participants received 10 practice trials (using stimulus pairs not used in the main experiment) to familiarize themselves with the task.

Results

In the informal post hoc interview, four participants in the picture-naming task reported that they had noticed the masked primes. The data from these participants were excluded from the entire analyses and hence the data from 80 participants were analyzed. Responses were preprocessed and manually corrected for voice-key errors via visual inspection of the speech waveform using CheckVocal software (Protopapas, 2007). Response latencies faster than 300 ms or slower than 1,300 ms were regarded as outliers and excluded from the entire analysis (0.3% of the data), resulting in 8,924 data points. Error responses (2.0%) were also excluded from the latency analyses, resulting in 8,763 data points. The mean response latencies and error rates are presented in Table 2.

In the analysis of the response latencies, we analyzed the data with linear mixed effect (LME) models (e.g., Baayen, Davidson, & Bates, 2008) using the lme4 package (D. Bates, Mächler, Bolker, & Walker, 2015) available in R (Version 3.5.0, R Development Core Team, 2018). A reciprocal inverse transformation was applied to the raw response latencies (Latency; i.e., −1,000/Latency; hereafter referred to as invLatency) to meet the assumption of normality. To calculate the p values with the degrees of freedom based on Satterthwaite's approximation, we used the lmerTest package in R (Kuznetsova, Brockhoff, & Christensen, 2017). In the analyses, task (picture naming vs. word naming), phonological overlap (match vs. mismatch), relatedness (related vs. unrelated), and block (1, 2, 3, and 4) were treated as fixed factors. Of these fixed factors, task, phonological overlap, and relatedness were contrast-coded as + 0.5/– 0.5. Conversely, forward difference coding was applied to block in order to examine whether the responses became faster as the blocks proceeded, creating three types of contrasts: 1 versus 2 (Contrast 1), 2 versus 3 (Contrast 2), and 3 versus 4 (Contrast 3).

As for model specification, we estimated the most parsimonious model (e.g., D. Bates, Kliegl, Vasishth, & Baayen, 2015; Matuschek, Kliegl, Vasishth, Baayen, & Bates, 2017) instead of using the maximal model (Barr, Levy, Scheepers, & Tily, 2013). In the model selection process, we progressively included random effect factors into the model if the model fit was improved signif-

Table 2
Mean Naming Response Latencies (Latency; in ms) and Error Rates (in Percentages) for Targets Primed by Match–Related, Match–Control, Mismatch–Related, and Mismatch–Control Kanji Words With Net Priming Effects in the Word-Naming and the Picture-Naming Tasks of Experiment 1

	Match prime			Mismatch prime		
Relatedness	Example	Latency	Error rate	Example	Latency	Error rate
Word-naming task						
Related	破産—葉巻 /**ha**-sa.N/–/**ha**-ma.ki/	523	1.2	拍手—葉巻 /**ha.ku**-sju/–/**ha**-ma.ki/	526	1.8
Control	遺産—葉巻 /**i**-sa.N/–/**ha**-ma.ki/	534	2.0	着手—葉巻 /**tja.ku**-sju/–/**ha**-ma.ki/	526	1.3
Priming effect		11	0.8		0	−0.5
Picture-naming task						
Related	破産—葉巻 /**ha**-sa.N/–/**ha**-ma.ki/	640	2.0	拍手—葉巻 /**ha.ku**-sju/–/**ha**-ma.ki/	652	2.7
Control	遺産—葉巻 /**i**-sa.N/–/**ha**-ma.ki/	654	2.3	着手—葉巻 /**tja.ku**-sju/–/**ha**-ma.ki/	650	2.5
Priming effect		14	0.3		−2	−0.2

Note. For all examples, boldface type highlights the phonology of the first character in a word.

icantly by adding a factor using a forward-selection heuristic with the chi-squared likelihood ratio test. That is, we first estimated a model including all the fixed factors and only the random intercepts for participants and targets. As only the random slope of block for participant and the slope of task for target improved the model fit significantly (both $ps < .001$), we reported the model including these terms. As a result, the final model formula for response latency analyses was as follows: invLatency ~ Task × Phonological Overlap × Relatedness × Block + (1 + Block | Participant) + (1 + Task | Target).

For the error analyses, we could not estimate the most parsimonious model because models repeatedly failed to converge. For the error analysis, therefore, we report the results based on four-way mixed ANOVAs with task (picture naming vs. word naming), phonological overlap (match vs. mismatch), relatedness (related vs. control), and block (1, 2, 3, and 4) as fixed factors. Task was a between-participants factor in the participant analyses but a within-item factor in the item analyses. Phonological overlap, relatedness, and block were both within factors in the participant and item analyses. In addition to the participant and item analyses, we also conducted *minF'* analyses (Clark, 1973). We thus considered an effect to be significant only when it was significant in the *minF'* analysis.

In the analysis of response latencies, the effect of task was significant (estimated coefficient = −0.351, SE = 0.047, $t = -7.466$, $p < .001$), reflecting faster responding in the word-naming task than in the picture-naming task. The main effect of phonological overlap was not significant (estimated coefficient = 0.002, SE = 0.004, $t = 0.555$, $p = .579$). The main effect of Relatedness was significant (estimated coefficient = 0.018, SE = 0.004, $t = 4.246$, $p < .001$), indicating faster responding for the related pairs than for the control pairs. The main effect of Contrast 1 (estimated coefficient = 0.056, SE = 0.011, $t = 5.303$, $p < .001$), and the main effect of Contrast 2 were significant (estimated coefficient = 0.033, SE = 0.010, $t = 3.425$, $p < .001$). The main effect of Contrast 3 was, however, not significant (estimated coefficient = 0.010, SE = 0.010, $t = 1.043$, $p = .300$). These results indicate that response latencies became successively shorter from the first to the third presentation, but there was no difference between the third and fourth presentations.

More important, the interaction between phonological overlap and relatedness was significant (estimated coefficient = −0.035, SE = 0.008, $t = -4.231$, $p < .001$). Separate analyses revealed that there was a significant masked priming effect in the match condition (estimated coefficient = 0.035, SE = 0.006, $t = 5.993$, $p < .001$), but there was no priming in the mismatch condition (|estimated coefficient| < 0.001, SE = 0.006, $t = -0.003$, $p = .996$). Replicating the results of Yoshihara et al. (2017), a masked priming effect was observed only when the prime and target shared the whole sound of their initial kanji characters. Critically, the three-way interaction among task, phonological overlap, and relatedness was not significant (estimated coefficient = −0.001, SE = 0.017, $t = -0.074$, $p = .941$). In addition, the four-way interaction among task, phonological overlap, relatedness, and block (Contrast 1 and Contrast 3) was not significant (both $ps > .05$), although the interaction between task, phonological overlap, relatedness, and Contrast 2 of block was significant (estimated coefficient = 0.103, SE = 0.047, $t = 2.161$, $p = .031$). The latter significant interaction was due to the fact that the masked priming effect in the match condition was reduced in the second block of the word-naming task (6 ms), whereas the effect apparently disappeared in the third block of the picture-naming task (−1 ms). It should be noted, however, that there was no hint of priming effect in any block of the mismatch condition (all $ts < 1.3$). Taken together, these results indicate that masked priming effects occurred only for the match pairs in both the word-naming and picture-naming tasks. In the analyses of error rates, no significant effect was observed (all *minF'* < 2.4).

Because our prediction partly concerned a null effect (i.e., no difference in the priming effect patterns between the tasks), we computed Bayes factors (BFs) to test the likelihood of the results favoring the null hypothesis over the alternative hypothesis (e.g., Kass & Raftery, 1995; Rouder, Morey, Speckman, & Province, 2012). The BF, which is essentially an odds ratio spreading from 0 to infinity, is generally seen as the weight of evidence provided by the data for H_0 (the null hypothesis) or H_1 (the alternative hypothesis). A BF of 1 indicates that the data provide equal evidence for H_0 and H_1. A value >1 favors H_0, and a value <1 favors H_1. Following Jeffreys' (1961) construal of the BF, a value between 1 and 3 constitutes "anecdotal" evidence for H_0, a value between 3 and 10 would be classified as "substantial," and a value between 10 and 30 would be considered as "strongly in favor" of H_0. In the response latency analysis, we computed the BF using the brms package (Bürkner, 2017) with the default priors and RStan package (Stan Development Team, 2018) available in R (Version 3.5.0, R Development Core Team, 2018). We compared two simpler models against the final model used in the LME analysis. First, when the four-way interaction term among task, phonological overlap, relatedness, and block was omitted from the final model, our BF was 222.5, favoring H_0 (i.e., the absence of the interaction) over the H_1 (i.e., the presence of the interaction). Second, when the three-way interaction term among task, phonological overlap, and relatedness was omitted from the final model, we found that our BF was 1681.4, favoring H_0 (i.e., the absence of the three-way interaction) over H_1 (i.e., the presence of the interaction). These results indicated that the priming effect patterns were not different between the tasks.[5] In the error rate analysis, we computed BFs in the same way as in the response latency analysis, except that we used the BayesFactor package (Morey & Rouder, 2018). In the participant analysis, we found that our BFs were 247.1 and 15.4 when the four-way and the three-way interactions were omitted, respectively. In the item analysis, our Bayes factors were 256.3 and 13.8 when the four-way and the three-way interactions were omitted, respectively. These results were again in favor of H_0 over H_1.

Discussion

In Experiment 1, we conducted word-naming and picture-naming tasks using word targets which are usually written only in kanji. The results showed that there was a significant masked priming effect in the match condition only, and this was the case for both tasks. The word-naming results were consistent with the

[5] Following the recommendation of Bürkner (2017), in the response latency analyses we computed the BF multiple times to evaluate the stability of the results. We report the mean values of BF based on 10 computations.

results of Yoshihara et al. (2017), and thus their main results were replicated successfully. More importantly, the picture-naming results were also in line with the word-naming results, showing a significant masked priming effect only when the shared mora sound corresponded to the whole sound of the initial kanji characters possessed by the prime and the target, even though the targets were pictures. These results seem to indicate that orthography (i.e., script type) does have an impact on speech production regardless of whether the phonology of a target word is directly derived from orthography (i.e., word naming) or from concepts (i.e., picture naming). Note that these results do not entirely resonate with the findings of Kureta et al. (2006) and Verdonschot and Kinoshita (2018). We further discuss this issue in the General Discussion.

Experiment 2: Test of Priming for Mismatch Pairs in the Picture-Naming Task

In Experiment 1, no masked priming effect was observed for the mismatch pairs, not only in the naming task but also in the picture-naming task. The latter was a novel and somewhat surprising finding, if one wishes to account for the results of Yoshihara et al. (2017) being due to the specific task used in their study. Hence, we conducted Experiments 2 and 3 to confirm that the null priming effect for the mismatch pairs in the picture-naming task is a reliable phenomenon.

Method

Participants. Forty-five undergraduate and graduate students from Waseda University participated in this experiment (age: M = 19.5 years, SD = 1.2). They were paid 500 JPY (~$US4.00) in exchange for their participation. All were native Japanese speakers with normal or corrected-to-normal vision. None had participated in Experiment 1.

Stimuli. We selected 28 two-character kanji words from which the critical picture targets were selected (see the Appendix, Table A2). The mean orthographic plausibility rating score was 4.9 on a five-point scale (Amano & Kondo, 2003a), indicating that these target words are normally written in kanji characters. The mean word frequency count for these targets was 18.2 per million (Amano & Kondo, 2003b). Two types of kanji primes (the mismatch-related and mismatch-control primes) were selected for each target. The mismatch-related prime shared an initial mora sound with the target, but the shared mora was only a part of the reading of the initial kanji character of the target (e.g., 我慢 **/ga**-ma.N/–楽譜 **/ga.ku**-hu/). For the mismatch-control prime, the first character was a different kanji character with a different mora sound and the second character was the same character with the same reading as the related prime (e.g., 自慢 **/zi**-ma.N/ vs. 我慢 **/ga**-ma.N/). Both related and control primes were orthographically unrelated to their targets (with no shared characters).

As shown in Table 3, the related and control primes were matched on the following variables: (1) the numbers of morae, (2) word frequency counts (Amano & Kondo, 2003b), (3) orthographic familiarity ratings (Amano & Kondo, 2003a), (4) phonological familiarity ratings (Amano & Kondo, 2003a), (5) orthographic neighborhood sizes (calculated using a database from the National Language Research Institute, 1993), (6) summed character frequencies (calculated using Amano & Kondo, 2003b), (7) the numbers of strokes, and (8) orthographic-phonological consistencies (calculated based on Hino et al., 2011; all Fs < 1). In addition, using the same procedure as in Experiment 1, the semantic relatedness ratings were also collected from 26 participants who did not participate in Experiment 2. The mean ratings for the mismatch-related and mismatch-control pairs were statistically comparable (M = 1.6 and 1.5; $F < 1.9$). Both prime types were therefore equally semantically unrelated to their targets.

Table 3
Statistical Characteristics of Mismatch-Related and Mismatch-Control Primes Used in Experiment 2

Lexical variable	Related prime[a]	Control prime[b]
Morae	3.0	3.0
Word frequency (per million)	10.6	9.6
Orthographic familiarity rating	5.6	5.6
Phonological familiarity rating	5.5	5.5
Orthographic neighborhood size	55.0	59.9
Summed character frequency	552,539	613,626
Number of strokes	18.6	18.9
Orthographic–phonological consistency index	.7	.7
Semantic relatedness rating	1.6	1.5

Note. All values are means. For all examples, boldface type highlights the phonology of the first character in a word.
[a] Example: 我慢—楽譜; /**ga**-ma.N/–/**ga.ku**-hu/. [b] Example: 自慢—楽譜; /**zi**-ma.N/–/**ga.ku**-hu/.

Based on these 56 prime–target pairs, we created two versions of the stimulus lists, each consisting of 28 prime–target pairs. Within each stimulus list, half of the targets (i.e., 14 items out of 28 targets) were paired with the related primes and the rest were paired with the control primes. Each participant received the two stimulus lists and thus each target was presented twice. Across the two stimulus lists, therefore, each target was paired with both types of primes. The order of the stimulus lists was counterbalanced across participants. Within each stimulus list, the presentation order of the prime–target pairs was randomized for each participant.

Apparatus and procedure. The apparatus and procedure were the same as those used in the picture-naming task of Experiment 1.

Results

In the post hoc interview, nine participants reported that they noticed the existence of the masked word primes. The data from these participants were excluded from further analysis, leaving the data from 36 participants to be submitted to statistical analysis. Responses were preprocessed and manually corrected for voice-key errors via visual inspection of the speech waveform using CheckVocal software (Protopapas, 2007). Response latencies faster than 300 ms or slower than 1,300 ms were regarded as outliers and excluded from the entire analysis (0.3% of the data). Error responses (2.1%) were also excluded from the latency analyses. These treatments left 1,970 and 2,011 data points for the latency analyses and the error analyses, respectively. The mean response latencies and error rates are presented in Table 4.

Table 4
Mean Naming Response Latencies (Latency; in ms) and Error Rates (in Percentages) for Picture Targets Primed by Mismatch-Related and Mismatch-Control Words With Net Priming Effect in Experiment 2

Relatedness	Latency	Error rate
Related[a]	624	2.5
Control[b]	628	1.7
Priming effect	4	−0.8

Note. For all examples, boldface type highlights the phonology of the first character in a word.
[a] Example: 我慢—楽譜; /**ga**-ma.N/–/**ga.ku**-hu/. [b] Example: 自慢—楽譜; /**zi**-ma.N/–/**ga.ku**-hu/.

We analyzed the response latencies in the same way as in Experiment 1. Relatedness (related vs. control) and block (1 and 2) were treated as fixed factors and contrast coded by +0.5/–0.5. Again, we estimated the most parsimonious model (e.g., D. Bates et al., 2015; Matuschek et al., 2017), using the forward-selection heuristic based on the chi-squared likelihood ratio test. As the random slope of block for participant significantly improved the model fit, the final model formula was invLatency ~ Relatedness × Block + (1 + Block | Participant) + (1 | Target). For the error analysis, we report the results from the two-way mixed ANOVAs with relatedness and block as fixed factors, including the results from the *min F'* ANOVA.

In the analysis of response latency, the main effect of Block was significant (estimated coefficient = 0.057, $SE = 0.014$, $t = 4.086$, $p < .001$), indicating that response latencies were shorter in the first presentation than in the second presentation. The main effect of relatedness and the interaction between relatedness and block were not significant (both $ts < 1$). This means that in the picture-naming task, there was no masked priming effect for the mismatch pairs. In the analysis of error rates, no effect was significant (all $minF' < 1.6$).

As in Experiment 1, because we predicted a null effect (i.e., no priming effect), we computed Bayes factors. In our RT analysis, the Bayes factor was 30.3, favoring H_0 over H_1, indicating that there was no masked priming effect. In the error rate analysis, our BFs were 11.0 and 10.8 for the results of participant and item analyses, respectively, again favoring H_0.

Discussion

In Experiment 2, again, there was no masked priming effect for the mismatch pairs in the picture-naming task. Thus, we confirmed that the null effect observed in Experiment 1 is a reliable phenomenon. The results are in line with the idea that speech production processes are affected by script type and that this is the case even when the phonology of an utterance is attained following the concept–lemma–lexeme route (Levelt et al., 1999).

There is, however, an alternative explanation for the absence of the priming effect that needs to be considered. During the learning phase of Experiments 1 and 2, each target picture was presented along with its kanji word (e.g., the kanji word 葉巻 was presented below the picture of a cigar), which could have allowed the picture name to be encoded with the orthographic information. This might have affected the results, as some researchers have indicated that visual presentation of a word's orthography might affect subsequent phonological encoding (e.g., Kureta et al., 2015; Li, Wang, & Idsardi, 2015). As stated earlier, Kureta et al. (2015) observed a significant phonemic form preparation effect when prompt-response word pairs were presented in Romanized alphabetic Japanese (Romaji), although no such effects were observed when the stimuli were presented in kana, kanji, or aurally. Therefore, in our Experiments 1 and 2, even though the targets were presented as pictures, the effect of orthography might not be eliminated due to the presentation of the picture name in kanji during the learning phase. To address this potential effect of orthography confounding the picture-naming results, we conducted an additional experiment.

Experiment 3: Picture-Naming Task Using Auditory Stimuli in the Learning Phase

In Experiment 3, we presented the picture names aurally in the learning phase, in order to confirm the null effect for the mismatch pairs in more rigorous settings. If the lack of the priming effect in Experiment 2 was due to the presentation of kanji characters in the learning phase, there would be a significant effect when the picture names were presented aurally. In contrast, if the specific procedure was not in charge of the null effect, no priming effect would be, again, observed.

Method

Participants. Forty-four undergraduate and graduate students from Waseda University participated in this experiment (age: M = 20.0 years, SD = 2.6). They were paid 500 JPY (~$US4.00) in exchange for their participation. All were native Japanese speakers with normal or corrected-to-normal vision. None had participated in any of the previous experiments.

Stimuli, apparatus, and procedure. The stimuli, apparatus, and procedure were the same as those in Experiment 2 except that the names of the target pictures were aurally presented in the learning phase. For each picture target, the picture name was aurally presented twice. The audio files were taken from Amano and Kondo (2003a).

Results

In the informal post hoc interview, three participants reported that they had noticed the masked primes. The data from these participants were excluded from the statistical analyses. Responses were preprocessed and manually corrected for voice-key errors via visual inspection of the speech waveform using CheckVocal software (Protopapas, 2007). The data from one participant were excluded because of high error rates (>15%), and thus the data from 40 participants were submitted to the statistical analyses. Response latencies faster than 300 ms or slower than 1,300 ms were regarded as outliers and excluded from the entire analysis (0.6% of the data). Error responses (2.0%) were also excluded from the latency analyses. These treatments left 2,185 and 2,227 data points for the latency analysis and error analysis, respectively. The mean response latencies and error rates are presented in Table 5. The response latencies (as well as the final model) and errors were analyzed in the same way as in Experiment 2.

Table 5
Mean Naming Response Latencies (Latency; in ms) and Error Rates (in Percentages) for Picture Targets Primed by Mismatch-Related and Mismatch-Control Words With Net Priming Effect in Experiment 3

Relatedness	Latency	Error rate
Related[a]	626	2.3
Control[b]	625	1.7
Priming effect	−1	−0.6

Note. For all examples, boldface type highlights the phonology of the first character in a word.
[a] Example: 我慢—楽譜; /**ga**-ma.N/–/**ga.ku**-hu/. [b] Example: 自慢—楽譜; /**zi**-ma.N/–/**ga.ku**-hu/.

In the analysis of response latency, the main effect of Block was significant (estimated coefficient = 0.063, $SE = 0.014$, $t = 4.646$, $p < .001$), indicating that response latencies were shorter in the first presentation than in the second presentation. The main effect of relatedness and the interaction between relatedness and block were not significant (both ts < 1.3). The BF was 42.5, favoring H_0 (i.e., the absence of the main effect of relatedness) over H_1 (i.e., a significant effect of relatedness). No significant effect was found in the analyses of error rates (all $minF' < 1$). Regarding the main effect of relatedness in the error analyses, the BFs for the participant and item analyses were 16.9 and 15.7, respectively, favoring H_0.

Discussion

In Experiment 3, the names of the picture targets were aurally presented in the learning phase in order to rule out the possibility that the exposure to the orthographic forms of the targets during the learning phase affected the results for the mismatch pairs in Experiments 1 and 2. Nonetheless, there was no hint of a masked priming effect, indicating clearly that the procedure used in the learning phase of our previous experiments was not responsible for the null effect.

Experiment 4: Replication of the Priming Effects for Match Pairs in the Picture-Naming Task

Thus far, we have repeatedly observed null priming effects for the mismatch pairs in the picture-naming task, which clearly indicates that the sole overlap of the initial mora between the prime and target is insufficient to produce priming effects even when the task is to name a picture (Experiments 1, 2, and 3). On the other hand, a significant priming effect was observed for the match pairs. This indicates that the overlap in the whole sound of each kanji character is critical for the masked priming effect in the word and picture-naming tasks. Recall, however, that the significant priming effect has been found only in Experiment 1 so far. In addition, the priming effect patterns might be confounded by the number of morae the initial kanji characters have. The initial kanji characters of the targets always corresponded to two consecutive morae when the masked priming effect was not found (Experiments 2 and 3; e.g., 楽譜/**ga.ku**-hu/), whereas they corresponded to a single mora when the effect was observed (Experiment 1; e.g., 葉巻/**ha**-ma.ki/). Thus, one might argue that a significant priming effect might be observed only when initial kanji characters correspond to a single mora (e.g., 破産 /**ha**-sa.N/–葉巻 /**ha**-ma.ki/). Although this seems unlikely, in Experiment 4 we addressed this issue in order to clearly demonstrate that the key to produce a priming effect is the fact that the initial characters had identical readings between the prime and target (and not the fact that the initial kanji character of a target consisted of a single mora), using a new set of stimuli. That is, we examined whether a significant priming effect is observed for the match prime–target pairs that shared multiple morae.[6]

Method

Participants. Thirty-six undergraduate and graduate students from Waseda University participated in this experiment (age: M = 21.5 years, SD = 4.2). They were paid 500 JPY (∼$US4.00) in exchange for their participation. All were native Japanese speakers with normal or corrected-to-normal vision. None had participated in Experiments 1, 2, or 3.

Stimuli. We selected 24 two-character kanji words for which critical picture targets were selected (see the Appendix, Table A3). The mean orthographic plausibility rating score was 4.9 on a five-point scale (Amano & Kondo, 2003a), indicating that these target words are normally written in kanji characters. The mean word frequency count for these targets was 2.8 per million (Amano & Kondo, 2003a). Two types of kanji primes (the match-related and match-control primes) and their respective control primes were selected for each target. The match-related prime shared two initial mora sounds with the target, and the shared morae made up the whole sound of the initial kanji character of the target (e.g., 目前 /**mo.ku**-ze.N/–木星 /**mo.ku**-se.i/). For the match-control prime, the first character was a different kanji character with a different mora sound and the second character was the same character with the same reading as the related prime (e.g., 目前 /**mo.ku**-ze.N/ vs. 直前 /**cho.ku**-ze.N/). Both related and control primes were orthographically unrelated to their targets.

As shown in Table 6, the related and control primes were matched on the following variables (1) the numbers of morae, (2) word frequency counts (Amano & Kondo, 2003b), (3) orthographic familiarity ratings (Amano & Kondo, 2003a), (4) phonological familiarity ratings (Amano & Kondo, 2003a), (5) orthographic neighborhood sizes (calculated using a database from the National Language Research Institute, 1993), (6) summed character frequencies (calculated using Amano & Kondo, 2003b), (7) the numbers of strokes, and (8) orthographic–phonological consistencies (calculated based on Hino et al., 2011; all Fs < 1.7). In addition, using the same procedure as in Experiments 1 and 2, the semantic relatedness ratings were also collected from another set of 26 participants who did not participate in Experiment 4. The mean ratings for the mismatch-related and mismatch-control pairs were statistically comparable (Ms = 2.1 and 2.0; $F < 1$). Both primes were therefore equally semantically unrelated to their targets.

Based on these 48 prime–target pairs, we created two versions of the stimulus lists, each consisting of 24 prime–target pairs. Within each of the stimulus lists, half of the targets (i.e., 12 out of 24 targets) were paired with the related primes and the rest with the

[6] We thank Padraig G. O'Séaghdha for pointing this out.

Table 6
Statistical Characteristics of Match-Related and Match-Control Primes Used in Experiment 4

Lexical variable	Related prime[a]	Control prime[b]
Morae	4.0	4.0
Word frequency (per million)	20.5	15.9
Orthographic familiarity rating	5.5	5.5
Phonological familiarity rating	5.2	5.2
Orthographic neighborhood size	54.3	67.7
Summed character frequency	756,731	769,770
Number of strokes	17.8	16.9
Orthographic–phonological consistency index	.8	.8
Semantic relatedness rating	2.1	2.0

Note. All values are means. For all examples, boldface type highlights the phonology of the first character in a word.
[a] Example: 目前—木星; /**mo.ku**-ze.N/–/**mo.ku**-se.i/. [b] Example: 直前—木星; /**cho.ku**-ze.N/–/**mo.ku**-se.i/.

control primes. Each participant received both stimulus lists and thus each target was presented twice. Across the stimulus lists, therefore, each target was paired with both types of primes. The order of the stimulus lists was counterbalanced across participants. Within each stimulus list, the presentation order of the prime–target pairs was randomized for each participant.

Apparatus and procedure. The apparatus and procedures were the same as those used in the picture-naming task of Experiment 3.

Results

In the post hoc interview, eight participants reported that they noticed the existence of the masked word primes. The data from these participants were excluded from further analysis and thus the data from 28 participants were submitted to statistical analysis. Responses were preprocessed and manually corrected for voice-key errors via visual inspection of the speech waveform using CheckVocal software (Protopapas, 2007). Response latencies faster than 300 ms or slower than 1,300 ms were regarded as outliers and excluded from the entire analysis (1.0% of the data). Error responses (3.4%) were also excluded from the latency analysis. With these procedures, 1,284 and 1,330 data points were left for the latency analysis and the error analysis, respectively. The mean response latencies and error rates are presented in Table 7.

The response latencies and errors were analyzed in the same way as in Experiments 2 and 3. Only the random slope of block for participant significantly improved the model fit, we decided to report the model including these terms. As a result, the final model for the latency analysis was invLatency $\sim$ Relatedness $\times$ Block + (1 + Block | Participant) + (1 | Target). In the analysis of response latency, the main effect of block was significant (estimated coefficient = 0.049, $SE = 0.018$, $t = 2.727$, $p = .011$), indicating that response latencies were shorter in the first presentation than in the second presentation. Importantly, the main effect of relatedness was significant (estimated coefficient = 0.042, $SE = 0.012$, $t = 3.467$, $p < .001$). The interaction between block and relatedness was not significant ($|t| < 2$). In Experiment 4, contrary to the preceding experiments, we computed the BF which is in favor of H_1 (i.e., a significant effect of relatedness) over H_0 (i.e., the absence of the main effect of relatedness) as the aim of this experiment was to ascertain whether there was a significant priming effect for the new match pairs. The results showed that our BF was 1.8×10^8, favoring H_1 over H_0, indicating that there was a significant priming effect.

In the analysis of error rates, no effect was significant (all Fs < 2.1). The BFs for the main effect of relatedness were 0.2 both in the participant and item analyses, not favoring H_1.

Discussion

In Experiment 4, a significant priming effect was found for the match pairs that shared initial multiple morae. This shows that the overlap of the whole sound of each kanji character, and not the number of morae the initial character has, is responsible for the significant masked priming effects in the picture-naming task.

General Discussion

Using a masked priming word-naming task with kanji compound words, Yoshihara et al. (2017) reported that a significant priming effect due to the initial mora overlap occurred only when the shared mora corresponded to the whole sound of the prime–target pairs' first characters. There was, however, no priming when the shared initial mora was only a part of the reading of the first kanji characters. These patterns of priming effects for kanji compound words was in contrast with the results of the previous masked priming naming study using kana stimuli (e.g., Verdonschot et al., 2011), which showed a significant facilitation due to the initial mora overlap between prime–target pairs. Note, however, that an aspect of the results in Yoshihara et al. was still in line with the data of Verdonschot et al. (2011). That is, when kanji compound word pairs were transcribed into kana, the standard initial mora-based effect emerged. These results therefore suggested that the orthography of stimuli (i.e., kana vs. kanji) might have an impact on the masked priming effects, and more broadly, on word production.

The only task used by Yoshihara et al. (2017) was word naming. It was thus possible that the pattern of priming effects observed for kanji compound words was specific to that task. That is, this type of results might emerge only under a situation in which orthography plays an essential role. In contrast, under situations in which the phonology of a to-be-spoken word is derived from the activation of concepts (e.g., picture naming), Yoshihara et al.'s results might not be replicated because orthography would play a much

Table 7
Mean Naming Response Latencies (Latency; in ms) and Error Rates (in Percentages) for Picture Targets Primed by Match-Related and Match-Control Words With Net Priming Effect in Experiment 4

Relatedness	Latency	Error rate
Related[a]	663	3.3
Control[b]	684	3.6
Priming effect	19	0.3

Note. For all examples, boldface type highlights the phonology of the first character in a word.
[a] Example: 目前—木星; /**mo.ku**-ze.N/–/**mo.ku**-se.i/. [b] Example: 直前—木星; /**cho.ku**-ze.N/–/**mo.ku**-se.i/.

smaller role in producing responses. The picture-naming task would reflect more spontaneous speech production process. Indeed, several previous studies on speech production have suggested that orthography does modulate performance only when the task involves visually presented word targets (e.g., Bi et al., 2009; Roelofs, 2006b). Thus, when the task is changed to picture naming, one might expect to observe a standard mora priming effect for kanji words (because the mora is assumed to be the fundamental phonological unit used in word production of Japanese). In the present study, we used the word and picture-naming tasks, and compared the patterns of priming effects.

In the word-naming task of Experiment 1, the main findings of Yoshihara et al. (2017) were successfully replicated. A significant priming effect was found for the match pairs (i.e., the prime–target pairs that shared an initial mora sound and the shared mora corresponded to the whole sound of their initial kanji characters; e.g., 破産 **/ha**-sa.N/–葉巻 **/ha**-ma.ki/). In contrast, no effect was found for the mismatch pairs (i.e., the prime–target pairs that shared an initial mora sound that did not correspond to the whole sound of their initial kanji characters; e.g., 拍手 **/ha.ku**-sju/–葉巻 **/ha**-ma.ki/).

The critical examination of the present study was whether the pattern of priming effects would be the same or different in the picture-naming and word-naming tasks. Our results clearly showed that the pattern was the same. In the picture-naming task of Experiment 1, although targets were pictures rather than words, a significant masked priming effect was observed only for the match pairs, whereas no priming effect was observed for the mismatch pairs. In Experiment 2, no priming for the mismatch pairs was replicated using a new set of stimuli. In Experiment 3, picture names were presented aurally, instead of visually, in the learning phase to eliminate any potential effects of word form information (orthography) affecting the later picture-naming performance. Still, no priming effect was observed for the mismatch pairs. Finally, in Experiment 4, we showed that priming effects also occurred for the match pairs that shared the initial two morae sounds, rather than one mora sound, demonstrating that the match in the whole sound of the prime's and target's first kanji characters is critical to produce a priming effect even in the picture-naming task.

In all, the present experiments confirmed that the results observed in the word-naming task (Yoshihara et al., 2017) were not a task-specific phenomenon but are generalizable to a different (i.e., picture-naming) task. That is, when participants produced naming responses for words (concepts) that are normally written in kanji, a significant priming effect occurred only when the whole sound of the initial kanji characters was shared between the prime–target pairs. More importantly, this was the case even when the orthographic forms of the target were never presented to the participants. An important implication of these results is that orthography of words affects the production of words not only when the target's phonology is retrieved directly from orthography but also when the phonology is retrieved through the concept–lemma–lexeme route (Levelt et al., 1999).

Phonological Encoding Processes in Word Naming and Picture Naming

The same pattern of priming effects observed in the word- and picture-naming tasks indicates that the underlying processes are likely to be shared between these two tasks. Although we assume that the phonological encoding processes are responsible for the present results, there might be an alternative account to be first considered. That is, one might argue that the masked priming effect for kanji words arises at the morphological encoding stage (and does not reflect orthographic influence on the phonological encoding processes). It is known that morphemic overlap facilitates speech production over and above any effects due to phonological overlap (e.g., Chen & Chen, 2007; Roelofs, 1996; Zwitserlood, Bölte, & Dohmes, 2000). For instance, Roelofs (1996) has shown that, using the associative-cuing task, the form preparation effect for Dutch stimuli was significantly larger when the shared initial syllable between response words in a homogeneous context constituted a morpheme (e.g., *bijvak* [subsidiary subject], *bijrol* [supporting role], *bijnier* [kidney]: *bij* is a morpheme meaning *additional* in these polymorphemic words) than when the shared syllable did not constitute a morpheme (e.g., *bijbel* [bible], *bijna* [almost], *bijster* [loss]: *bij* is not a morpheme in these monomorphemic words). As each kanji character stands for a morpheme, and both word naming and picture naming are assumed to involve the morphological encoding (e.g., Levelt et al., 1999; Roelofs, 2004), the present masked priming effects might also reflect facilitation which arises at the morphological encoding process. However, it is difficult to assume the morphologically based facilitation in the present experiments, simply because none of the prime–target pairs shared any characters and meanings, which means that they never shared morphemes (e.g., 破産 **/ha**-sa.N/ *bankruptcy*–葉巻 **/ha**-ma.ki/ cigar).[7]

Rather, as noted in the introductory paragraphs of this article, we assume that the present masked priming effects occurred at the phonological encoding process, during which reading aloud (word naming) and speaking (picture naming) processes are assumed to be converged (Roelofs, 2004). Specifically, Roelofs (2004) suggested that word- and picture-naming processes are merged at the "segmental spell-out" process, in which the stored phonological representation of a word is decomposed into segmental information such as phonemes (Levelt et al., 1999; cf. Holbrook, Kawamoto, & Liu, 2019). If the masked priming effect arises at the shared process, there would be no reason to expect different patterns of the effects between the tasks. Consistent with this assumption, we observed the same patterns of the masked priming effects in both tasks. In addition, in line with the present study, a previous masked priming study (You et al., 2012) that used Mandarin Chinese did find equivalent patterns of masked priming in word-naming tasks and picture-naming tasks (i.e., facilitation due to syllabic overlap). Furthermore, Price et al. (2006) reported, in their fMRI study, that the same main brain regions were activated when participants were naming a picture and when they were reading a word (e.g., left and right premotor cortices, left posterior superior temporal regions, and precuneus), though the reading task produced more activation in general. As these areas were more strongly activated when a vocal response was required (e.g., the picture-naming task) than when a manual response was required

[7] Note, however, that it would be important to further investigate whether/how the orthographic influence indicated in the present study can be detached from the morpheme level in a more direct way. We thank Padraig G. O'Séaghdha for pointing out this concern.

(e.g., object recognition task), these areas are associated with speech production processes in both the word-reading and picture-naming tasks. These results appear to indicate that (at least a part of) phonological processing for speech production is shared between the word reading and picture-naming tasks. As such, the possibility exists that the present masked priming effects reflect the shared process between the word-naming and picture-naming tasks, namely, phonological encoding (see also Valente, Pinet, Alario, & Laganaro, 2016).

Note that it might be warranted to further discuss this possibility from the viewpoint of the intersection between perception and production, as discussed in Chen et al. (2016). There is in general a distinction between input phonology of perception and output phonology for production (e.g., Nozari, Kittredge, Dell, & Schwartz, 2010). However, although word naming (as well as recognizing a masked prime) involves perception of a visually presented word, whereas picture naming is deemed as a "pure" production process, the same masked priming patterns imply that perception and production of phonology intersect at the phonological encoding stage. In the same vein, Nozari et al. (2010) also suggested an overlap between perceptual and production processes. They found, based on analyses of data from English aphasic patients and computational simulations, that both auditory word repetition and picture-naming tasks were significantly affected by lexical variables such as word frequency in the same way. Here, auditory word repetition involves perceptual process of an aurally presented word, although the main goal is to produce a heard word. As the word frequency effect is assumed to arise in accessing the phonological word form, the results in Nozari et al. indicated that the phonological encoding stage is shared between auditory word repetition and picture naming. It would be worthwhile to investigate to what degree perceptual and production processes overlap with each other in future research.

It should also be noted that we are not claiming that the underlying mechanisms are completely the same between the word-naming and picture-naming tasks. Rather, these tasks include different processes, as shown in the literature (e.g., Alario et al., 2007; Bi et al., 2009; E. Bates, Burani, D'Amico, & Barca, 2001; Roelofs, 2006a, 2006b). For instance, the significantly longer RTs observed in the picture-naming task (Experiment 1) are consistent with the notion that in the picture-naming task participants must identify the appropriate referent of a picture target from the concept, whereas in the word-naming task they do not (e.g., Levelt et al., 1999).

Orthographic Influence on Speech Production

How does, then, orthography affect speech production? Under the assumption that the present results reflect the phonological encoding processes, we suggest that the whole sound of each kanji character becomes available during those processes because orthography of a target is activated online in both word-naming and picture-naming tasks. Although most people would agree that orthography is activated in a word-naming task, one might doubt that the orthographic activation occurs in a picture-naming task. Contrary to this suspicion, researchers have reported evidence for the automatic activation of orthography even when a target is a picture (e.g., Price et al., 2006; Rastle et al., 2011; Zhao et al., 2012). For instance, Rastle et al. (2011) observed an orthographic effect (i.e., spelling–sound consistency effect) in the picture-naming task using the word learning paradigm. They argued that the result indicates that orthography is automatically activated online in that task, even though orthographic information is irrelevant for performing the task. As such, it is reasonable to assume orthographic activation in a picture-naming task (and of course in a word-naming task).

If orthography of a kanji target word is activated, it would in turn constrain the phonological encoding processes. Specifically, the segmental spell-out process would be affected by the character-to-sound mappings. As a result, the whole sound of each kanji character becomes available as a chunk, rather than in a sequential mora by mora manner (e.g., Yoshihara et al., 2017). This idea seems consistent with the findings of Tamaoka (2005), who compared naming latencies for single kanji characters that varied in their mora length. Tamaoka predicted that if a kanji's phonology is activated serially, naming latencies for kanji characters with more morae would become slower because more processing time would be needed. The naming latencies, however, did not differ for kanji characters that had one mora sound (e.g., 手 /te/), two mora sounds (e.g., 月/tu.ki/) and three mora sounds (e.g., 体/ka.ra.da/). In contrast, when these kanji characters were transcribed into kana (hiragana), there was a significant effect of the mora length. According to Tamaoka, these results provide empirical support for the idea that the phonology of kanji is activated and processed as a whole.[8]

It should be noted that we do not deny the assumption that the default size of phonological unit for Japanese speech production is the mora. In fact, the results in the previous studies have indicated that the fundamental phonological unit inserted into the metrical frame would be the mora (e.g., Kureta et al., 2006; Roelofs, 2015; Verdonschot & Kinoshita, 2018; Verdonschot et al., 2011). Although Yoshihara et al. (2017) indicated the possibility that the phonological unit of Japanese kanji words is the whole sound of each kanji character, it might be unlikely that such unit is inserted into the metrical frame. Nevertheless, it is difficult to explain the results of the present experiments if one assumes that only the mora is used in the phonological encoding of Japanese words. The present results clearly indicate that the whole sound of each kanji character is involved when producing naming responses. We suggest that it would be at the process in which phonology of a word is decomposed (i.e., the segmental spell-out process, at which word naming and picture naming are assumed to be merged, e.g., Roelofs, 2004). That is, when producing a Japanese word that is usually written in kanji (e.g., 木星 **/mo.ku**-se.i/), the whole sound of each character would also be spelled out (e.g., **/mo.ku/** and /se.i/), not only the each mora (e.g., **/mo/**, **/ku/**, /se/, and /i/). We assume, as discussed in the following text, that such a (rather redundant) phonological encoding would be due to the nature of the character-to-sound mappings of kanji characters.

[8] In contrast to our interpretation of Tamaoka's (2005) kanji word-naming data, one might argue that his data rather indicate that the morae for a kanji character are activated in parallel but that only the initial mora needs to be encoded for articulation. This would explain the null effect of the morae length for kanji stimuli. We are, however, reluctant to accept this interpretation because it is unclear why such was not the case for kana stimuli.

As Yoshihara et al. (2017) have put forward, the psycholinguistic grain size theory might offer an account of how orthography constrains phonological encoding (e.g., Goswami, Ziegler, Dalton, & Schneider, 2003; Goswami, Ziegler, & Richardson, 2005; Ziegler & Goswami, 2005, 2006; Ziegler, Perry, Jacobs, & Braun, 2001). The grain size theory assumes that the size of phonology used in phonological processing (i.e., the phonological grain size) develops differently depending on the nature of orthographic–phonological relationships. A small phonological grain size rapidly develops in languages that have shallow or highly transparent orthographic–phonological relationships (e.g., Italian, Dutch). In languages that have deeper and less transparent relationships (e.g., English, French), on the other hand, small phonological grain sizes are relatively difficult to develop, and hence larger grain sizes become more important. Note that in most languages, there is only a single script and therefore there is in general only one type of orthographic–phonological relationship. As a result, the grain size theory has often been discussed in terms of cross-language differences.

In the case of Japanese, however, it is the key to discuss the different developmental courses of the phonological grain sizes within the language because the orthographic-phonological relationships are different between kana and kanji scripts (e.g., Feldman & Turvey, 1980; Frost, 2005; Saito, 1981; Wydell, Butterworth, & Patterson, 1995). It is generally assumed that kana is shallow and transparent, whereas kanji is deep and opaque. Therefore, the phonological grain size of kanji might be much larger than that of kana. Particularly, as each kana character corresponds to a single, unique mora sound (e.g., the kana character か is always read as **/ka/**), Japanese children would learn to read kana-written words based mainly on the consistent character–mora relationships. This simple mapping might lead to develop a mora-sized (small) phonological grain. For kanji characters, on the other hand, each character does not necessarily correspond to a single mora sound but in many cases to multiple morae (e.g., Hino, Kusunose, Miyamura, & Lupker, 2017). Further, each kanji character typically has more than one correct reading. In fact, according to Tamaoka, Makioka, Sanders, and Verdonschot (2017), more than 60% of the standard (Jôyô) kanji characters have multiple readings of different moraic sizes (e.g., the kanji 紫, *purple*, is read *shi*, corresponding to one mora, when appearing in the word 紫外線 **/si**-ga.i-se.N/ *ultra violet* but *mu.ra.sa.ki*, corresponding to four morae, when appearing in the word 紫色 **/mu.ra.sa.ki**-i.ro/ *purple*). Thus, unlike kana characters, there is no fixed relationship regarding how many morae each kanji character is mapped onto, and it is impossible to allocate any specific "amount" of mora to each kanji character. As a result, children would use individual (inconsistent) character-sound relationships when learning to read written kanji words. Hence, its phonological grain would be the whole sound of each character (i.e., a larger grain size).

Assuming that the phonology of kanji becomes available as a whole in the phonological encoding processes when orthography is activated, we are able to explain the present results: masked priming occurred only when a prime and a target shared the whole sound of the initial kanji characters in both the word and picture-naming tasks. To illustrate this concretely, we take the 目前 **/mo.ku**-ze.N/–木星 **/mo.ku**-se.i/ pair used in Experiment 4 as an example (i.e., the match pairs). Upon the presentation of the prime word 目前, its orthographic representation is first activated, and the phonology would then be decomposed into the whole sound of each kanji character. That is, the phonology of the first kanji character (/mo.ku/) is accessed as a whole in the phonological encoding processes, rather than as individual morae (**/mo/** and **/ku/**). (Possibly the same also occurs for the second kanji character 前/ze.N/.) Similarly, for the target 木星, as its orthography is activated, the same phonological chunk (/mo.ku/) is accessed in the phonological encoding processes of both the word-naming and picture-naming tasks. As the same phonology is accessed for both the prime and target (目前 and 木星), a significant priming effect is expected in the two tasks. Parallel results were indeed observed in Experiment 1 (word and picture naming) and Experiment 4 (picture naming). In contrast, there was no priming effect in Experiments 2 and 3 because the different phonology was used by the prime and target (e.g., /ga/ for the prime, 我慢 /ga-ma.N/, and /ga.ku/ for the target, 楽譜 /ga.ku-hu/).

On the other hand, if prime–target pairs are words usually written in kana (e.g., モデル /mo.de.ru/ *model*), each kana characters are activated and, hence, the phonology is decomposed into each mora based on the consistent character–mora relationships (e.g., /mo/, /de/, and /ru/), resulting in a (simple) mora priming effect (e.g., Verdonschot et al., 2011). In addition (see Experiment 3 of Yoshihara et al., 2017), if kanji stimuli are transcribed into kana characters (note that in many cases, this would turn them into nonwords in the sense that they lose visual familiarity), then the orthographic presentation of kana would facilitate the access to the mora-sized grains. As a result, the standard mora priming effect would be observed. As such, it is possible to explain the different masked priming effect patterns between kanji (Yoshihara et al., 2017; the present study) and kana (Verdonschot et al., 2011; Yoshihara et al., 2017, Experiment 3), with the assumption that the segmental spell-out process of the phonological encoding is modulated by the character-to-sound mappings as a result of orthographic activation.

We acknowledge, however, that further investigation is clearly needed as studies of Japanese speech production have shown inconsistent (though interesting) results. Whereas we have demonstrated orthographic influence on the masked priming effect, no difference has been reported between kanji and kana words in the other paradigm (e.g., the form preparation paradigm with the associative-cuing task, Kureta et al., 2006; the phonological Stroop task, Verdonschot & Kinoshita, 2018). It is, therefore, necessary to determine what caused the discrepancies and which paradigm/task is most suited to reflect the nature of the phonological encoding processes. For instance, as noted in the Introduction, although the simple mora-based form preparation effect was observed for kanji and kana stimuli (Kureta et al., 2006), it might reflect not (only) the phonological encoding but the memory retrieval processes (e.g., Alario et al., 2007; O'Séaghdha & Frazer, 2014). In addition, Verdonschot and Kinoshita (2018) argued that differences in the task demands might have somehow influenced the latency patterns differently between the phonological Stroop task (Verdonschot & Kinoshita, 2018) and the masked priming word-naming task (Yoshihara et al., 2017). In the former task, no direct processing is required for the kanji characters, as the task is to name the ink colors of the characters, whereas in the latter task, it is necessary to retrieve phonology directly from the presented kanji characters. But our results do not follow such an explanation. Using a picture-naming task, the task involving no direct processing for kanji characters, we did replicate the results previously observed in the word-naming task. Thus, it would be necessary to investigate other factors which might cause the discrepancy, considering various differences between the tasks such as the presentation time of distractors and primes (e.g., stimulus-onset asynchrony, prime duration), the types of stimulus words (e.g., single kanji characters vs. kanji compound words and targets that are usually not depicted in kanji, e.g., ワニ *crocodile*), and the orthographic plausibility of distractors and targets (i.e., color names are occasionally written in kana, whereas the picture names used in the present study are normally written only in kanji).

Conclusions

To investigate whether orthography affects the masked priming effect patterns and speech production, we examined the masked priming effect for kanji words using word-naming and picture-naming tasks. The results showed that in both tasks the masked priming effect was observed only when the prime–target pairs shared the whole sound of their initial kanji characters, indicating that orthography has an influence on speech production. In our view this effect occurs as kanji orthography can exert an effect during phonological encoding. Note, however, that although our results are consistent between the word-naming and picture-naming tasks, our data are still inconsistent with the data in several earlier studies. Hence, additional experimentation is necessary to provide a satisfactory theoretical account to explain the available data.

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Appendix A

Stimuli Used in the Present Experiments

Table A1
Target–Prime Pairs Used in Experiment 1

Target	Match–Related prime	Match–Control prime
位牌 /**i**-ha.i/ *mortuary tablet*	威力 /**i**-rjo.ku/ *power*	武力 /**bu**-rjo.ku/ *military power*
遺跡 /**i**-se.ki/ *remains*	異論 /**i**-ro.N/ *objection*	持論 /**zi**-ro.N/ *cherished opinion*
宇宙 /**u**-tju.U/ *the universe*	右翼 /**u**-jo.ku/ *the right wing*	左翼 /**sa**-ajo.ku/ *the left wing*
絵本 /**e**-ho.N/ *picture book*	獲物 /**e**-mo.no/ *prey*	魔物 /**ma**-mo.no/ *demon*
火山 /**ka**-za.N/ *volcano*	貨物 /**ka**-mo.tu/ *cargo*	荷物 /**ni**-mo.tu/ *baggage*
仮面 /**ka**-me.N/ *mask*	歌人 /**ka**-zi.N/ *Waka poet*	詩人 /**si**-zi.N/ *poet*
化石 /**ka**-se.ki/ *fossil*	加算 /**ka**-sa.N/ *addition*	誤算 /**go**-sa.N/ *miscalculation*
花壇 /**ka**-da.N/ *flower bed*	仮名 /**ka**-me.i/ *allonym*	地名 /**cji**-me.i/ *the name of a place*
機械 /**ki**-ka.i/ *machine*	起立 /**ki**-ri.tu/ *standing*	都立 /**to**-ri.tu/ *metropolitan*
気球 /**ki**-kju.U/ *balloon*	記帳 /**ki**-tjo.u/ *register*	手帳 /**te**-tjo.u/ *notebook*
貴族 /**ki**-zo.ku/ *noble*	危害 /**ki**-gai.i/ *injury*	自害 /**zi**-ga.i/ *suicide*
着物 /**ki**-mo.no/ *kimono*	喜劇 /**ki**-ge.ki/ *comedy*	悲劇 /**hi**-ge.ki/ *tragedy*
孔雀 /**ku**-zja.ku/ *peacock*	区分 /**ku**-bu.N/ *division*	二分 /**ni**-bu.N/ *bisect*
小銭 /**ko**-ze.ni/ *coin*	個室 /**ko**-si.tu/ *single room*	和室 /**wa**-si.tu/ *Japanese-style room*
磁石 /**zi**-sja.ku/ *magnet*	地雷 /**zi**-ra.i/ *mine*	魚雷 /**gjo**-ra.i/ *torpedo*
指紋 /**si**-mo.N/ *fingerprint*	資材 /**si**-za.i/ *material*	機材 /**ki**-za.i/ *equipment*
地蔵 /**zi**-zo.u/ *Jizo*	自慢 /**zi**-ma.N/ *pride*	我慢 /**ga**-ma.N/ *patience*
車輪 /**sja**-ri.N/ *wheel*	社名 /**sja**-me.i/ *company name*	無名 /**mu**-me.i/ *nameless*
写真 /**sja**-si.N/ *picture*	車体 /**sja**-ta.i/ *the body of a car*	死体 /**si**-ta.i/ *dead body*
朱肉 /**sju**-ni.ku/ *ink pad*	首長 /**sju**-tjo.u/ *chief*	機長 /**ki**-tjo.u/ *captain*
書道 /**sjo**-do.u/ *calligraphy*	初演 /**sjo**-e.N/ *premiere*	主演 /**sju**-e.N/ *leading actor*
地球 /**cji**-kju.U/ *the earth*	治安 /**cji**-a.N/ *public security*	保安 /**ho**-a.N/ *public security*
仁王 /**ni**-o.u/ *the two Deva Kings*	煮物 /**ni**-mo.tu/ *boiled dishes*	刃物 /**ha**-mo.no/ *edged tool*
葉巻 /**ha**-ma.ki/ *cigar*	破産 /**ha**-sa.N/ *bankruptcy*	遺産 /**i**-sa.N/ *heritage*
波紋 /**ha**-mo.N/ *ripple*	破裂 /**ha**-re.tu/ *explosion*	亀裂 /**ki**-re.tu/ *crack*
舞台 /**bu**-ta.i/ *stage*	部員 /**bu**-i.N/ *member*	署員 /**sjo**-i.N/ *staff member*
野菜 /**ja**-sa.i/ *vegetable*	家賃 /**ja**-cji.N/ *rent*	駄賃 /**da**-cji.N/ *reward*
屋台 /**ja**-ta.i/ *booth*	夜間 /**ja**-ka.N/ *in the night*	区間 /**ku**-ka.N/ *section*
	Mismatch–Related prime	Mismatch–Control prime
位牌 /**i**-ha.i/	引火 /**i.N**-ka/ *ignition*	噴火 /**hu.N**-ka/ *eruption*
遺跡 /**i**-se.ki/	逸話 /**i.tu**-wa/ *anecdote*	実話 /**ji.tu**-wa/ *true story*
宇宙 /**u**-tju.U/	運河 /**u.N**-ga/ *canal*	銀河 /**gi.N**-ga/ *the Milky Way*
絵本 /**e**-ho.N/	塩素 /**e.N**-so/ *chlorine*	酸素 /**sa.N**-so/ *oxygen*
火山 /**ka**-za.N/	角度 /**ka.ku**-do/ *angle*	極度 /**kjo.ku**-do/ *extreme*
仮面 /**ka**-me.N/	快 挙 /**ka.i**-kjo/ *brilliant achievement*	大挙 /**ta.i**-kjo/ *in full force*
化石 /**ka**-se.ki/	漢字 /**ka.N**-zi/ *kanji characters*	点字 /**te.N**-zi/ *Braille*
花壇 /**ka**-da.N/	活気 /**ka.Q**-ki/ *vigor*	熱気 /**ne.Q**-ki/ *hot air*
機械 /**ki**-ka.i/	禁固 /**ki.n**-ko/ *imprisonment*	断固 /**da.N**-ko/ *firm*
気球 /**ki**-kju.U/	金魚 /**ki.N**-gjo/ *goldfish*	鮮魚 /**se.N**-gjo/ *fresh fish*
貴族 /**ki**-zo.ku/	近所 /**ki.N**-gjo/ *neighborhood*	便所 /**be.N**-zjo/ *lavatory*
着物 /**ki**-mo.no/	近視 /**ki.N**-si/ *shortsightedness*	乱視 /**ra.N**-si/ *astigmatism*
孔雀 /**ku**-zja.ku/	君主 /**ku.N**-sju/ *monarch*	民主 /**mi.N**-sju/ *democracy*
小銭 /**ko**-ze.ni/	国語 /**ko.ku**-go/ *National language*	落語 /**ra.ku**-go/ *comic story*
磁石 /**zi**-sja.ku/	人種 /**zi.N**-sju/ *race*	品種 /**hi.N**-sju/ *variety*
指紋 /**si**-mo.N/	震度 /**si.N**-do/ *seismic intensity*	温度 /**o.N**-do/ *temperature*
地蔵 /**zi**-zo.u/	陣地 /**zi.N**-cji/ *encampment*	団地 /**da.N**-cji/ *housing complex*
車輪 /**sja**-ri.N/	尺度 /**sja.ku**-do/ *scale*	速度 /**so.ku**-do/ *speed*
写真 /**sja**-si.N/	借家 /**sja.ku**-ja/ *rented house*	楽屋 /**ga.ku**-ja/ *dressing room*
朱肉 /**sju**-ni.ku/	出火 /**sju.Q**-ka/ *outbreak of fire*	発火 /**ha.Q**-ka/ *combustion*
書道 /**sjo**-do.u/	承知 /**sjo.u**-cji/ *consent*	周知 /**sju.U**-cji/ *well-known*
地球 /**cji**-kju.U/	陳謝 /**cji.N**-sja/ *apology*	感謝 /**ka.N**-sja/ *appreciation*
仁王 /**ni**-o.u/	任意 /**ni.N**-i/ *voluntary*	真意 /**si.N**-i/ *one's real intention*
葉巻 /**ha**-ma.ki/	拍手 /**ha.ku**-sju/ *handclap*	着手 /**tja.ku**-sj/ *commencement*
波紋 /**ha**-mo.N/	配布 /**ha.i**-hu/ *distribution*	財布 /**sa.i**-hu/ *purse*
舞台 /**bu**-ta.i/	分布 /**bu.N**-pu/ *distribution*	散布 /**sa.N**-pu/ *spraying*
野菜 /**ja**-sa.i/	役目 /**ja.ku**-me/ *role*	低目 /**hi.ku**-me/ *rather low*
屋台 /**ja**-ta.i/	躍起 /**ja.Q**-ki/ *get excited*	決起 /**ke.Q**-ki/ *rising to action*

Note. Each of the examples comprise the word, its pronunciation, and the English translation. For all examples, boldface type highlights the phonology of the first character in a word.

(*Appendix continues*)

Table A2
Target–Prime Pairs Used in Experiments 2 and 3

Target	Related prime	Control prime
市場 **/i.cji**-ba/ *market*	異論 **/i**-ro.N/ *objection*	持論 **/zi**-ro.N/ *cherished opinion*
岩場 **/i.wa**-ba/ *rocky area*	威力 **/i**-rjo.ku/ *power*	武力 **/bu**-rjo.ku/ *military power*
腕輪 **/u.de**-wa/ *bracelet*	右翼 **/u**-jo.ku/ *the right wing*	左翼 **/sa**-ajo.ku/ *the left wing*
映画 **/e.i**-ga/ *movie*	獲物 **/e**-mo.no/ *prey*	煮物 **/ni**-mo.tu/ *boiled dishes*
楽譜 **/ga.ku**-hu/ *musical score*	我慢 **/ga**-ma.N/ *patience*	自慢 **/zi**-ma.N/ *pride*
空手 **/ka.ra**-te/ *karate*	仮名 **/ka**-me.i/ *allonym*	地名 **/cji**-me.i/ *the name of a place*
金魚 **/ki.N**-gjo/ *goldfish*	危害 **/ki**-gai.i/ *injury*	自害 **/zi**-ga.i/ *suicide*
競馬 **/ke.i**-ba/ *horse race*	毛玉 **/ke**-da.ma/ *pill of wool*	目玉 **/me**-da.ma/ *eyeball*
工事 **/ko.u**-zi/ *construction*	故人 **/ko**-zi.N/ *the deceased*	詩人 **/si**-zi.N/ *poet*
紅茶 **/ko.u**-tja/ *tea*	個体 **/ko**-ta.i/ *individual*	車体 **/sja**-ta.i/ *the body of a car*
財布 **/sa.i**-hu/ *purse*	作法 **/sa**-ho.u/ *manners*	魔法 **/ma**-ho.u/ *magic*
刺身 **/sa.si**-mi/ *sashimi*	差額 **/sa**-ga.ku/ *the balance*	巨額 **/kjo**-ga.ku/ *large amount*
色紙 **/si.ki**-si/ *message board*	資材 **/si**-za.i/ *material*	機材 **/ki**-za.i/ *equipment*
神社 **/zi.N**-zja/ *shrine*	地雷 **/zi**-ra.i/ *mine*	魚雷 **/gjo**-ra.i/ *torpedo*
水車 **/su.i**-sja/ *water mill*	素顔 **/su**-ga.o/ *natural face*	笑顔 **/e**-ga.o/ *smile*
星座 **/se.i**-za/ *constellation*	背筋 **/se**-su.zi/ *spine*	血 筋 **/cji**-su.zi/ *blood relationship*
掃除 **/so.u**-zi/ *cleaning*	祖国 **/so**-ko.ku/ *mother country*	母国 **/bo**-ko.ku/ *mother country*
太鼓 **/ta.i**-ko/ *drum*	多数 **/ta**-su.U/ *many*	戸数 **/ko**-su.U/ *the number of houses*
天狗 **/te.N**-gu/ *long-nosed goblin*	手前 **/te**-ma.e/ *this side*	自前 **/zi**-ma.e/ *one's own*
忍者 **/ni.N**-zja/ *ninja*	荷物 **/ni**-mo.tu/ *baggage*	貨物 **/ka**-mo.tu/ *cargo*
白衣 **/ha.ku**-i/ *white robe*	破産 **/ha**-sa.N/ *bankruptcy*	遺産 **/i**-sa.N/ *heritage*
花火 **/ha.na**-bi/ *firework*	波及 **/ha**-kju.U/ *spread*	普及 **/hu**-kju.U/ *popularization*
文具 **/bu.N**-gu/ *stationery*	部員 **/bu**-i.N/ *member*	署員 **/sjo**-i.N/ *staff member*
帽子 **/bo.u**-si/ *hat*	母体 **/bo**-ta.i/ *mother's body*	死体 **/si**-ta.i/ *dead body*
丸太 **/ma.ru**-ta/ *log*	真顔 **/ma**-ga.o/ *serious look*	寝顔 **/ne**-ga.o/ *sleeping face*
迷路 **/me.i**-ro/ *maze*	目先 **/me**-sa.ki/ *near future*	手先 **/te**-sa.ki/ *pawn*
木馬 **/mo.ku**-ba/ *wooden horse*	模様 **/mo**-jo.u/ *pattern*	仕様 **/si**-jo.u/ *specification*
牢屋 **/ro.u**-ja/ *jailhouse*	路面 **/ro**-me.N/ *road surface*	斜面 **/sja**-me.N/ *slope*

Note. Each of the examples comprise the word, its pronunciation, and the English translation. For all examples, boldface type highlights the phonology of the first character in a word.

(*Appendix continues*)

Table A3
Target–Prime Pairs Used in Experiment 4

Target	Related prime	Control prime
階段 **/ka.i**-da.N/ *stairway*	海水 **/ka.i**-su.i/ *sea water*	排水 **/ha.i**-su.i/ *draining*
靴下 **/ku.tu**-si.ta/ *socks*	屈辱 **/ku.tu**-zjo.ku/ *humiliation*	雪辱 **/se.tu**-zjo.ku/ *revenge*
拳銃 **/ke.N**-zju.U/ *gun*	見学 **/ke.N**-ga.ku/ *field trip*	文学 **/bu.N**-ga.ku/ *literature*
剣道 **/ke.N**-do.u/ *Japanese fencing*	堅実 **/ke.N**-zi.tu/ *steady*	真実 **/si.N**-zi.tu/ *truth*
札束 **/sa.tu**-ta.ba/ *a wad of bills*	殺害 **/sa.tu**-ga.i/ *murder*	実害 **/zi.tu**-ga.i/ *actual harm*
水槽 **/su.i**-so.u/ *water tank*	睡眠 **/su.i**-mi.N/ *sleeping*	快 眠 **/ka.i**-mi.N/ *a good sleep*
水道 **/su.i**-do.u/ *waterworks*	推定 **/su.i**-te.i/ *inference*	内定 **/na.i**-te.i/ *informal decision*
赤飯 **/se.ki**-ha.N/ *rice boiled with red beans*	石材 **/se.ki**-za.i/ *stone*	適材 **/te.ki**-za.i/ *the right person for the job*
雪原 **/se.ki**-ge.N/ *snowfield*	説明 **/se.tu**-me.i/ *explanation*	失明 **/si.tu**-me.i/ *blindness*
銭湯 **/se.N**-to.u/ *public bath*	先月 **/se.N**-ge.tu/ *last month*	前月 **/ze.N**-ge.tu/ *the previous month*
草原 **/so.u**-ge.N/ *grass field*	総会 **/so.u**-ka.i/ *general meeting*	教会 **/kjo.u**-ka.i/ *church*
竜巻 **/ta.tu**-ma.ki/ *tornado*	達人 **/ta.tu**-zi.N/ *a master*	殺人 **/sa.tu**-zi.N/ *homicide*
探偵 **/ta.N**-te.i/ *detective*	単発 **/ta.N**-pa.tu/ *one-shot*	反発 **/ha.N**-pa.tu/ *repellence*
竹林 **/ti.ku**-ri.N/ *bamboo forest*	築城 **/ti.ku**-zjo.u/ *castle construction*	落城 **/ra.ku**-zjo.u/ *the fall of a castle*
電柱 **/de.N**-chu.U/ *telegraph pole*	伝染 **/de.N**-se.N/ *infection*	感染 **/ka.N**-se.N/ *infection*
灯台 **/to.u**-da.i/ *lighthouse*	党 員 **/to.u**-i.N/ *party member*	教員 **/kjo.u**-i.N/ *teacher*
白菜 **/ha.ku**-sa.i/ *Chinese cabbage*	薄情 **/ha.ku**-zjo.u/ *coldhearted*	欲情 **/jo.ku**-zjo.u/ *lust*
白米 **/ha.ku**-sa.i/ *polished rice*	博学 **/ha.ku**-ga.ku/ *erudition*	薬学 **/ja.ku**-ga.ku/ *pharmacy*
花束 **/ha.na**-ta.ba/ *bouquet*	鼻唄 **/ha.na**-u.ta/ *humming*	舟唄 **/hu.na**-u.ta/ *sailor's song*
覆面 **/hu.ku**-me.N/ *mask*	副業 **/hu.ku**-gjo.u/ *sideline*	悪業 **/a.ku**-gjo.u/ *bad act*
宝石 **/ho.u**-se.ki/ *jewelry*	法学 **/ho.u**-ga.ku/ *jurisprudence*	共学 **/kjo.u**-ga.ku/ *coeducation*
木刀 **/bo.ku**-to.u/ *wooden sword*	牧牛 **/bo.ku**-gju.U/ *grazing cattle*	肉牛 **/ni.ku**-gju.U/ *beef cattle*
盆栽 **/bo.N**-sa.i/ *potted plant*	凡 人 **/bo.N**-zi.N/ *ordinary man*	恩人 **/o.N**-zi.N/ *benefactor*
木星 **/mo.ku**-se.i/ *jupiter*	目前 **/mo.ku**-ze.N/ *before one's eyes*	直前 **/tjo.ku**-ze.N/ *immediately before*

Note. Each of the examples comprise the word, its pronunciation, and the English translation. For all examples, boldface type highlights the phonology of the first character in a word.

Received April 9, 2018
Revision received January 8, 2020
Accepted January 22, 2020 ■