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The Functional Unit of Japanese Word Naming: Evidence From Masked Priming

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Theories of language production generally describe the segment as the basic unit in phonological encoding (e.g., Dell, 1988; Levelt, Roelofs, & Meyer, 1999). However, there is also evidence that such a unit might be language specific. Chen, Chen, and Dell (2002), for instance, found no effect of single segments when using a preparation paradigm. To shed more light on the functional unit of phonological encoding in Japanese, a language often described as being mora based, we report the results of 4 experiments using word reading tasks and masked priming. Experiment 1 demonstrated using Japanese kana script that primes, which overlapped in the whole mora with target words, sped up word reading latencies but not when just the onset overlapped. Experiments 2 and 3 investigated a possible role of script by using combinations of romaji (Romanized Japanese) and hiragana; again, facilitation effects were found only when the whole mora and not the onset segment overlapped. Experiment 4 distinguished mora priming from syllable priming and revealed that the mora priming effects obtained in the first 3 experiments are also obtained when a mora is part of a syllable. Again, no priming effect was found for single segments. Our findings suggest that the mora and not the segment (phoneme) is the basic functional phonological unit in Japanese language production planning.

Keywords: onset priming, Japanese, language production, phonological unit

Although languages throughout the world display a great deal of variation, most research on language production has focused on West Germanic and Romance languages, such as English, Dutch, and French. As a consequence, many theories of language production (e.g., Dell, 1988; Levelt et al., 1999) have proposed, in one way or the other, that word-form construction is performed by incrementally clustering phonological segments (phonemes) into syllabic patterns. For instance, for the word *Japan,* the segments /dʒ/ and /ə/ would be clustered into the first syllable, /dʒə/, and the next three segments, /p/ /æ/ /n/, would be clustered into /pæn/, thereby creating the phonological form /dʒə -pæn/. However, the functional unit size may differ substantially between languages. For instance, Meyer (1991) and Roelofs (2006), using a so-called implicit priming task, also known as the preparation paradigm (a paradigm that we describe in more detail later), found that Dutch target words that overlapped in the first phoneme (e.g., *boek, bijl, beer* [book, axe, bear]) were read aloud faster than words that differed in their first phoneme, indicating that the first phoneme of a word (a subsyllabic segment) is a functional unit in Dutch. In contrast, Chen et al. (2002; Experiment 5), using the same task, found that when to-be-named Mandarin Chinese target words overlapped in the first phoneme (e.g., *mo, ma, mu, mi*), no facilitation effect was apparent. Facilitation was found, however, when words overlapped in the complete first syllable. Chen et al. (2002) concluded that Mandarin Chinese does not allow planning at a subsyllabic level and that syllables (not segments) are the functional units linked to speech production in Mandarin Chinese. This is in agreement with Chen, Lin, and Ferrand (2003), who reached a similar conclusion from data obtained in a masked priming study.

The idea of variable functional unit size between languages is furthermore in line with results obtained by Ferrand, Segui, and Grainger (1996), who investigated the role of sublexical phonological units (in particular the syllable) in French. Using a masked

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priming technique, in which participants were required to read aloud words (or name pictures), while keeping the amount of overlap (in segments) between masked prime words and targets constant, they manipulated whether or not the prime constituted a whole syllable. For instance, the consonant–vowel (CV) prime /ba/ constitutes the whole first syllable of *BA.LADE,* but it is only part of the first syllable of *BAL.CON.* Furthermore, the consonant–vowel–consonant (CVC) prime /bal/ transcends the first syllable of *BA.LADE,* whereas it makes up the whole first syllable of *BAL.CON.* Ferrand et al. always obtained greater priming (facilitation) when the prime equaled the syllable than when it did not. This effect was also found in nonword and picture naming. However, the effect disappeared in a lexical decision task, indicating that the syllable priming effect likely finds its origin in the generation of articulatory output, which, according to Ferrand et al., is syllabically structured in French.

This is in contrast to results obtained by Schiller (1998), who in Dutch (using the same paradigm as the previous study; i.e., masked priming in word and picture naming) found that CVC primes always caused greater priming than CV primes. These results indicate that the syllable does not constitute a functional unit in the production of Dutch phonology as it does in French (see, however, Brand, Rey, & Peereman, 2003, for a failure to replicate the syllable effect in French). In fact, Schiller (1998) found that the more segments overlap between prime and target, the more priming will be obtained in Dutch, leading to the *segmental overlap hypothesis* (for similar findings in English, see Schiller, 2000). In the current study, we aim to extend the discussion of language-specific functional units to Japanese, a language that has been argued to be mora timed, in contrast to stress-timed Dutch and English and syllable-timed French and Chinese (see Port, Dalby, & O'Dell, 1987; Warner & Arai, 2001).

In Japanese phonology, a distinction can be made between the syllable and the mora. For instance, a word such as *nihon* (Japan) consists of two syllables (*ni* and *hoN*; N = nasal coda), but one can further divide this word into three moras (e.g., *ni.ho.N).* Moras are considered metrical units. They typically correspond to an equal number of kana symbols (Japanese script; e.g., にほん), and each mora is assumed to be generally constant in duration (e.g., /ni/, /ho/, and /N/ last roughly equally long). Therefore, in Japanese, moras (such as the nasal coda) form an independent rhythmical structure within a syllable. The range of Japanese moras is quite limited, with only 108 different items divided into five types (Otake, Hatano, Cutler, & Mehler, 1993): CV (consonant–vowel), CCV (consonant–consonant–vowel), V (vowel), N (nasal coda), and Q (geminate). Japanese words usually involve simple moraic CV combinations (e.g., /ka/ or /mi/), which, in CV form, equal a syllable. However, other combinations are also possible. For example, long vowels take two moras (e.g., [CVV] 脳 /nou/ "brain"), and geminate elements (e.g., [CVQ.CV] 切手 /kiQ.te/ "stamp") and nasal coda elements (e.g., [CVN] 本 /hoN/ "book") also take one mora each. Furthermore, a diphthong (VV) takes one mora per element (e.g., [VV.CV] 英語 /ei.go/ "English"). See Table 1 for an overview of a selection of some Japanese words and their properties.

As stated, mora structures in Japanese are well reflected in the *kana* script, which constitutes moraic symbols divided into *hiragana* and *katakana*. These scripts were adapted from the more complicated logographic kanji characters to allow a more precise phonological representation of native Japanese vocabulary words and their inflectional morphology. The kana scripts are phonological in nature by being based on a one-to-one correspondence of kana to mora, but their usage differs. Katakana is mainly used to represent loanwords, typically those from languages with alphabetic writing systems, proper nouns, and proper names from foreign languages (e.g., マクドナルド /ma.ku.do.na.ru.do/ for "McDonald's," the fast-food restaurant). Hiragana, on the other hand, is used for native elements in the language, such as function words, inflectional affixes, and onomatopoeia, as well as those borrowings that have been assimilated into the language.

Evidence demonstrating that the mora plays an important role in language production comes from speech errors. For instance, Kubozono (1989) found that Japanese are more likely to elicit errors that respect mora boundaries; for example, /toma(re)/ "stop!" and /(suto)Qpu/ "stop!" would be blended into /to.maQ.pu/ (thereby including the geminate [= mora] and not simply the last syllable). Furthermore, many Japanese language games also respect moraic structure. Consider a game played by children (and adults), such as shiritori (Katada, 1990, p. 641), in which players have to come up with a follow-up word that starts with the last element (i.e., mora) of the previously heard word. For example, when /kao/ "face" is heard, /oN.ga.ku/ "music" would be a valid answer, indicating that not the entire diphthong but only the last mora (i.e., /o/) is important. When a player says /ka.mi/ "paper/god/hair," a good continuation would be /mi.zu/ "water"; however, /mi.zu/ cannot be followed by /zu.boN/ "trousers," because Japanese has no word that begins with a nasal coda. As such, the player would lose the game.

Empirical evidence that the mora plays an important role in the Japanese language comes from studies on speech segmentation (e.g., Cutler & Otake, 1994; Otake et al., 1993). In these studies, participants were required to monitor Japanese words for the

Table 1
Example of Japanese Words Differing in Structure, Syllable, and Number of Moras

Word meaning	Kanji	Transcription	Kana	Structure[a]	Syllables	Moras
paper	紙	/ka.mi/	かみ	CV.CV	2	2
book	本	/hoN/	ほん	CVN	1	2
stamp	切手	/kiQ.te/	きって	CVQ.CV	2	3
English	英語	/ei.go/	えいご	VV.CV	2	3
dragon	龍	/ryuu/	りゅう	CjVV	1	2

[a] CV = consonant–vowel; N = nasal coda; Q = geminate; VV = diphthong; Cj = consonant with palatal glide (C+, や ゆ よ).

appearance of specific strings of segments, for example, CV ("na") or CVN ("naN"). No detection advantage was found for CV structures whether they were part of a CV.CV.CV or a CVN.CV target word, contrary to what a syllable hypothesis would predict (CVN.CV being more difficult, as CV target is only part of the syllable CVN). In addition, CVN targets (e.g., "naN") were much easier to detect in CVN.CV words such as "naN.ka," where the nasal coda served as a separate mora, than in "na.no.ka," where the target is only part of a mora. These patterns were not obtained when the same experiment was repeated with English participants, leading Otake et al. (1993) and Cutler and Otake (1994) to conclude that Japanese speech segmentation respects mora boundaries.[1]

However, there could be other factors playing a role, such as the type of task being used. This becomes evident as Otake and Cutler (2003) found using a word reconstruction paradigm that participants were sensitive to submoraic (e.g., segmental) information. In this paradigm, participants had to judge whether auditorily presented nonwords could be reconstructed into real words. Otake and Cutler showed that participants found it easier to reconstruct /ka.me.ra/ from nonwords that had a partial mora preserved, such as /ki.me.ra/ and /na.me.ra/, than from /ni.me.ra/, in which the whole mora was different. In a subsequent lexical decision task, participants heard words and nonwords for which the so-called nonword uniqueness point (i.e., the point in the word when it starts differing from a real word; e.g., the "i" in *Japin*), was manipulated. Otake and Cutler found that the sooner a word became a nonword, the faster participants could reject it. In their regression analysis, duration and phoneme (but not moras) significantly accounted for a portion of the variance as independent predictors. Therefore, Otake and Cutler concluded that segmental information contributes to word recognition. This is in line with findings reported by Tamaoka and Taft (1994), who presented participants with katakana strings to which a word/nonword judgment had to be made (lexical decision task). Participants found it harder to reject /ko.me.ra/, which is one mora and one phoneme different from the real loanword /ka.me.ra/, than /so.me.ra/, which is one mora and two phonemes different. Tamaoka and Taft concluded therefore that participants were sensitive to segmental information when processing Japanese kana.

A more recent study by Kureta, Fushimi, and Tatsumi (2006) directly investigated the functional encoding unit in Japanese speech production using the preparation (or implicit priming) paradigm (e.g., Meyer, 1991). In this paradigm, participants are typically required to learn small sets of semantically related word pairs (called prompt–response pairs). Participants are subsequently asked to produce the corresponding response word upon presentation of a prompt; for instance, a participant should respond by saying "ring" after seeing the prompt *marriage.* Creating small blocks differing in phonological consistency can influence the presence and absence of priming. For instance, prompts can be presented that result in phonologically congruent (or homogeneous) blocks, such as *rule, rain, ring* (all starting with the phoneme /r/), or prompts can be presented that have no phonological relationship (so-called heterogeneous blocks), such as *cloud, book, ring.* Reaction times typically are shorter in the homogeneous blocks than in the heterogeneous blocks when there is phonological congruency in the first syllable (but not the rhyme; see Meyer, 1991). Kureta et al. (2006) found that for Japanese this form preparation effect occurred only when initial consonant and vowel (CV) were similar (e.g., *katsura, kabuki, kaban*) and not when just the consonant or consonant plus palatal glide (Cj) were similar (e.g., *katsura, kujira, kofun* and *gyakuten, gyuuniku, gyousei*, respectively). Kureta et al. concluded on the basis of these data that the mora plays a crucial role in the construction of the phonological form of a Japanese word. Although their study was well designed and their results and interpretation were clear cut, there are some additional issues that, in our view, deserve further examination.

One important issue concerns the fact that although Kureta et al. (2006) used different scripts (to avoid character repetition in homogenous blocks; e.g., かつら[*katsura*; hiragana], 歌舞伎[*kabuki*; kanji], and 鞄[*kaban*; kanji]), they did not include stimuli written in romaji (Romanized Japanese; e.g., using alphabetic script). Kureta et al. did not include these words, as words written in romaji have a low orthographic plausibility (i.e., a subjective rating scale concerning the preferred orthographic form in which a particular word is usually written; Amano & Kondo, 1999). However, including romaji would have had the benefit of including a script that involves processing of individual phonemes (as in languages with an alphabetic script). Although the orthographic plausibility is low, romaji is taught at primary school, and many Japanese frequently use romaji to input Japanese text on computers, cell phones, and other electronic devices. Therefore, many Japanese are well able to read and write Japanese using romaji.

In summary, there are studies demonstrating contrasting effects (e.g., Cutler & Otake, 1994 [speech segmentation] vs. Otake & Cutler, 2003 [word reconstruction]) with respect to functional unit size. Yet, a study by Kureta et al. (2006) yielded preparation effects for the whole mora only and not the segment.

We believe that although there is a growing body of evidence for the mora as a functional unit of phonological encoding in Japanese (e.g., Kureta et al., 2006), it is not conclusive at this moment. In this paper, we are especially interested in whether the so-called masked onset priming effect (MOPE), a form priming effect due to the initial segment only, can be found in Japanese. This, to our knowledge, has not previously been tested. The MOPE refers to the finding that when a target word (e.g., *HOME*) is preceded by a prime word sharing the onset (e.g., *hill*) briefly presented under visually masked conditions, reading aloud of the target is facilitated compared to when prime (e.g., *pill*) and target (*HOME*) do not share their onset (e.g., Forster & Davis, 1991; Grainger & Ferrand, 1996; Schiller, 2004; for a review, see Kinoshita, 2003). Forster and Davis proposed that the MOPE originates in the nonlexical route in naming, that is, when the sublexical phonology from a letter string is computed from its orthography (also called orthography-to-phonology conversion, or OPC). In contrast, Kinoshita (2000) proposed that the locus of the MOPE occurs later than OPC (i.e., at the level of phonological encoding

[1] It is worthwhile to mention that in the speech segmentation literature an effect of script on segmentation has been shown. Inagaki, Hatano, and Otake (2000) compared Japanese preschool children who were not yet able to read with older Japanese children who were able to read kana (moraic script). They found that the literate children (e.g., who could read kana) shifted their segmentation preference from a syllable-based representation toward a mora-based representation.

of the speech response), in what she termed the *speech-planning account*. In particular, the phonologies from the prime and the target are proposed to compete for a slot during the segment-to-frame association process in speech planning. A mismatch between the onset of the prime and target will cause an inconsistency in the speech plan, and resolving this conflict comes at a processing cost and, hence, takes longer (Kinoshita & Woollams, 2002).

In this paper, we examine native speakers of Japanese using a masked priming paradigm to establish whether or not a MOPE can be found in Japanese. If so, this could be taken as evidence that the phoneme can function as an independent functional planning unit.

A factor of influence, as argued earlier, could be the role of script in the detection and processing of phonological information. Consider, for instance, findings from two masked priming experiments using Korean by Kim and Davis (2002), who found a (marginal) onset effect when primes and targets were presented in hangul (script favoring segments) but not when the target was presented in hanja (a script favoring syllables). They concluded that the underlying nature of the script may have been responsible for the discrepancy in results between the two experiments. Such findings may be interpreted in terms of the nature of target script governing the units that drive the phonological encoding process, mediated by the unit of the orthography-to-phonology mapping process. That is, when the target script is alphabetic, as in Korean Hangul, Cyrillic script, and romaji, the phonology would likely become available segment by segment, and the segment-to-frame association process of the target, as the name implies, could indeed proceed on a segment-by-segment basis. A MOPE could be observed in this case because the segmental information in the prime overlapping with the target is useful: The target script allows the phonological encoding process to proceed in a segment-by-segment fashion.

In contrast, when the target script is hanja, the target phonology would become available only in the syllable-sized unit. In this case, the segment-to-frame association process of the target could proceed syllable by syllable but not segment by segment; hence, overlapping segmental information made available by the hangul prime may not produce onset priming. Thus, manipulating the target script in Japanese (mora-based kana vs. segment-based romaji) is important for interpreting the presence or absence of a MOPE: It may either be because segments are not the functional unit of phonological encoding in Japanese or because the unit of orthography-to-phonology mapping was not a segment. On the reasonable assumption that the nature of target script governs the unit of orthography-to-phonology mapping, a MOPE in Japanese may depend on the nature of the target script. In contrast, if the functional unit of phonological encoding in Japanese is a mora and not a segment, a MOPE should be absent even when the target script is segmental (e.g., romaji).

We present the empirical results of four experiments. Throughout the experiments, the degree of overlap was always manipulated from one consonantal segment in the MOPE condition (e.g., target: *ka.ze*; primes: *ko.to* vs. *so.to*) to whole mora (CV) overlap (e.g., target: *ka.ze*; primes: *ka.mi* vs. *na.mi*). The first experiment was aimed to ascertain whether the masked priming paradigm could provide empirical results that could distinguish between onset and mora priming. The second and third experiments investigated the possible role of script (i.e., does romaji allow for onset priming more than does kana). The fourth experiment was aimed to distinguish mora from syllable priming by introducing C and CV primes in nasal coda and geminated targets (e.g., CVN.CV and CVQ.CV). We hypothesized that if the mora (and not the phoneme or syllable) reflects the functional phonological unit in Japanese, we should obtain a priming effect only when the whole mora overlaps. However, if the paradigm (masked vs. implicit priming) and/or script type (kana vs. romaji) indeed have an influence, we may also expect segmental priming effects (e.g., MOPE) to surface.

Experiment 1: Segment vs. Mora Priming

In the first experiment, the participants' task was to name hiragana strings that were presented on the computer screen. Targets were preceded by masked primes, and participants were divided into two groups. In both groups, the target was presented in hiragana (e.g., すし /su.shi/), but although the MOPE group also received the primes in hiragana (e.g., せん /seN/ vs. れん /reN/) the mora group received the primes in katakana (e.g., スミ /su.mi/ vs. グミ /gu.mi/) to avoid visual repetition. As Japanese does not have capital letters, presenting both prime and target in hiragana in the MOPE setting would amount to a complete visual repetition (e.g., すみ/su.mi/ – すし/su.shi/). If the segment functions as an independent unit in Japanese, we would expect to find priming effects in both groups, with perhaps a larger effect for the mora group (as more segments are overlapping). If the mora and not the segment functions as an independent planning unit, we would expect to find priming effects only in the mora group.

Method

Participants. Twenty-two undergraduate students from Yamaguchi University, Yamaguchi, Japan (15 female, 7 male; average age = 20.3 years, SD = 1.3), took part in the MOPE (segment overlap) part of this experiment, and 20 undergraduate students from Reitaku University, Kashiwa, Japan (15 female, 5 male; average age = 23.7 years, SD = 4.9), took part in the MORA (mora overlap) part. All students received financial compensation for their participation. All participants were native speakers (and fluent readers) of Japanese and had normal or corrected-to-normal vision.

MOPE stimuli. Forty-two bi-moraic words were selected as targets, and an additional 42 bi-moraic, semantically unrelated words were selected as primes. All words (primes and targets) were selected such that a broad variety of moras appeared at the first position (e.g., ka, ki, ku, ke, ko; sa, shi, su, se, so). Primes and targets were presented in hiragana (Japanese syllabic script). There was no visual overlap between prime and target (e.g., target かぜ/kaze/ with the onset prime こと/koto/ vs. the control prime そと/soto/). Some mora combinations appear more frequently than others, for instance, the bi-moraic combination こと/koto/ is more frequent than the bi-moraic combination カオ /kao/ (for more information, see the openly accessible database on bi-moraic frequencies on http://www.lang.nagoya-u.ac.jp/~ktamaoka/down_en.htm). Mora frequencies are assumed to have some effects on naming latencies, as shown by Tamaoka and Makioka (2009), who found that when naming nonwords high-frequency intial moras were named faster than were low-frequency initial moras. However, bi-mora frequencies showed a less prominent role when naming actual words than nonwords. Nonetheless, whenever possible, primes were matched to form pairs, thereby avoiding bi-moraic frequency effects (e.g., the target せき/seki/ was paired with the onset prime そと/soto/ vs. the control prime こと/koto/).

MORA stimuli. Thirty bi-moraic words from the same corpus as the MOPE stimuli were selected as targets, and an additional 30 bi-moraic, semantically unrelated words were selected as primes. As the MORA prime and target when both presented in hiragana have complete character repetition, primes were presented in katakana and targets were presented in hiragana. Care was taken to avoid onset moras having visually matching characteristics in both scripts; for example, words starting with "ka" (hiragana: か; katakana: カ) were not selected. Whenever possible the MORA primes formed pairs to avoid any frequency effects. See Appendix A for an overview of the stimuli used in these two parts of Experiment 1.

Design. In both the MOPE and MORA parts of this experiment, targets were preceded either by an overlapping prime (first segment in the MOPE case or complete mora in the MORA case) or by a control prime. Participants in the MOPE part received 84 trials, and participants in the MORA part received 60 trials. Pseudo-random lists were constructed for each individual participant such that phonologically or semantically related primes or targets had at least a distance of two trials to avoid unintended priming effects.

Procedure. In all reported experiments, the software package E-Prime 2.0 combined with a voice key was used for stimulus presentation and data acquisition. Participants were seated approximately 60 cm from a 17-in. LCD computer screen (Eizo Flexscan P1700 with a screen cycle refresh rate of 60 Hz) in a quiet room at Yamaguchi University (MOPE part) or Reitaku University (MORA part) and were tested individually. After a short explanation of the experimental paradigm and two warm-up trials, participants started the experiment proper. A trial comprised the presentation of a fixation cross (750 ms) followed by a forward mask consisting of hash marks (##; 500 ms) and subsequently a hiragana (MOPE part) or katakana (MORA part) prime (50 ms) that was replaced immediately by the target, which disappeared when the participant responded or after maximally 3,000 ms. Masks, primes, and targets were presented with the MS Mincho font (36 pt). All items appeared as black characters on white background. Target words consisted of two hiragana characters, which covered about 1.5° × 2.7° of visual angle. After each trial, the experimenter recorded the accuracy of the response. There was a short break halfway through the experiment, and then two warm-up trials preceded the continuation of the experiment. Naming latencies were measured from target onset. Participants were specifically instructed to respond as fast as possible while avoiding errors. They were not informed about the existence of the prime. After the experiment, informal interviewing showed that participants were generally unaware of the presentation of the primes.

Results

MOPE results. Naming latencies exceeding three standard deviations per participant per condition and voice-key errors were excluded from the analysis (6.7% of the data). As errors were few (1.7% of the data) and were equally distributed across conditions, an error analysis was not performed. The reaction time analysis showed that there were no significant priming effects for onset overlap compared to control primes, $ts < 1$, min $F'(1, 31) < 1$.

MORA results. Naming latencies exceeding three standard deviations per participant per condition and voice-key errors were excluded from the analysis (7.7% of the data). As errors were few (0.1% of the data) and were equally distributed across conditions, an error analysis was not performed. The reaction time analysis revealed that there was a significant priming effect (15 ms) when the whole mora prime overlapped compared to control, $t_1(19) = 3.72$, $SD = 18.11$, $p < .01$; $t_2(29) = 3.45$, $SD = 24.23$, $p < .01$, min $F'(1, 47) = 6.40$, $p < .001$ (see Table 2 for an overview).

Discussion

The results of Experiment 1 show no effect of onset priming but do show an effect of mora overlap priming. This suggests that the functional unit in Japanese language production is not the segment but the mora. However, it should be noted that prime and target were presented in moraic kana (hiragana/katakana) script, which does not favor individual activation of segmental elements and as such might have led to the observed pattern of results. Furthermore, in the MORA prime group, there was a script switch between prime and target (from katakana to hiragana) that was absent in the MOPE prime group (both hiragana). This might have led to the shorter reaction times observed for this group and in turn, due to a floor effect, might have obscured a potential priming effect. Therefore, we decided to include romaji stimuli in Experiments 2 and 3 to determine whether or not including a script favoring the processing of segments might lead to different results. Experiment 4 addressed the script change issue.

Experiment 2: The Effects of Kana and Romaji Scripts on Masked Onset Priming

This experiment was designed to examine whether the findings of Experiment 1 could be replicated in an experimental situation that uses visually presented segmental information. Experiment 2 employed hiragana and romaji targets, which were all preceded by romaji primes. If the type of script used caused the absence of onset priming in Experiment 1, Experiment 2 should remedy this situation. If, however, Japanese do plan their speech in moraic units, then Experiment 2 should not show any onset priming either, despite the romaji script advantage toward the segment.

Table 2
Mean Naming Latencies (in Ms) and Error Rates (in %) in Experiment 1 on the MOPE and MORA Groups as a Function of Relatedness (Overlap and Control)

	MOPE prime group (n = 22)		MORA prime group (n = 20)	
Condition	RT (SD)	Error rate	RT (SD)	Error rate
Control	519 (59)	1.6	597 (26)	0.0
Overlap	520 (65)	1.8	582 (27)	0.2
Priming effect	−1	−0.2	15	−0.2

Note. MOPE = masked onset priming effect; MORA = mora overlap; RT = reaction time; SD = standard deviation.

Method

Participants. Forty undergraduate students from Nagoya University, Nagoya, Japan (25 female, 15 male; average age = 22.6 years, $SD = 4.8$) took part in this experiment in exchange for financial compensation. All participants were native speakers (and fluent readers) of Japanese and had normal or corrected-to-normal vision.

Stimuli. Forty-two bi-moraic words were selected as targets, and an additional 42 bi-moraic, semantically unrelated words were selected as primes (see Appendix B). Using the pairing procedure from Experiment 1, we combined these targets with the primes to form 168 target–prime pairs. Targets appeared either in hiragana or in romaji (capitals). All primes were in romaji.

Design. A 2 (target type: hiragana or romaji) × 2 (prime type: MOPE or MORA) × 2 (relatedness: overlap vs. control) within-subjects factorial design was implemented. Frequent repetition of targets and primes was avoided by subjecting each participant to only two repetitions instead of eight per target, resulting in 84 trials per participant. All 42 targets were presented once in romaji and once in hiragana. To ensure that each condition for each target type and prime type appeared equally often, we assigned participants to individually generated, pseudo-random lists generated by E-Prime 2.0. The lists were constructed such that MORA and MOPE conditions for the whole experiment appeared equally often per target type. Furthermore, in these lists phonologically or semantically related primes or targets had at least a distance of two trials to avoid unintended priming effects. Between participants, the design included all of the experimental conditions. Within participants, the order of target type (romaji or hiragana) was counterbalanced.

Procedure. The apparatus was the same as in the first experiment. Participants were tested individually in a quiet room at Nagoya University. The trial sequence was identical to that in Experiment 1. Masks, primes, and targets were displayed in Courier New font (28 pt). All items appeared in the center of the screen as black characters on white background. Each uppercase romaji target word covered approximately 0.95° of visual angle from a viewing distance of 60 cm. Romaji target words were four or five letters in length, subtending between 2.7° and 3.2° of visual angle. Hiragana targets consisted of two mora characters and covered about 0.95° × 1.6° of visual angle.

Results

Naming latencies exceeding three standard deviations per participant per condition and voice-key errors were excluded from the analysis (1.0% of the data). As errors were few (1.3% of the data), an error analysis was not performed. Please see Table 3 for an overview of the results. There was a main effect of target type (hiragana or romaji), indicating that targets in hiragana were read aloud 221 ms faster than targets in romaji, $F_1(1, 39) = 215.10$, $MSE = 18{,}170.98$, $p < .001$; $F_2(1, 41) = 675.14$, $MSE = 6{,}076.46$, $p < .001$; min $F'(1, 62) = 163.1$, $p < .001$. Furthermore, there was a main effect of relatedness in the subject analysis (overlap vs. control), $F_1(1, 39) = 5.48$, $MSE = 3{,}021.98$, $p < .05$; $F_2(1, 41) = 2.03$, $MSE = 3{,}710.03$, $p = .161$; min $F'(1, 67) = 1.48$, $p = .23$. Target type interacted significantly with relatedness in the subject analysis, $F_1(1, 39) = 6.92$, $MSE = 2{,}307.84$, $p < .05$, and approached significance in the item analysis, $F_2(1, 41) = 3.61$, $MSE = 4{,}258.12$, $p = .07$; min $F'(1, 74) = 2.37$, $p = .13$. Given this interaction, we conducted paired t tests for each target type, prime type, and trial type. These t tests showed that there were no significant effects when target types were hiragana (ts < 1). When the target type was romaji, there was a significant priming effect (33 ms) when the whole mora overlapped, $t_1(39) = 2.64$, $SD = 79.22$, $p < .05$; $t_2(41) = 2.02$, $SD = 95.23$, $p < .05$, but not when only the first segment (16 ms) overlapped, $t_1(39) = 1.26$, $SD = 82.71$, $p = .214$; $t_2 < 1$.

Discussion

Reading romaji takes significantly more time (221 ms) than reading hiragana. This could account for the absence of priming effects from romaji primes during hiragana target naming. The prime might simply be too late to exert an influence. However, when the target is also in romaji (and also takes more time to read), both prime and target are delayed, thereby again allowing for priming effects to surface, as evidenced by our results. In the latter case, it is again found that facilitation from priming becomes significant only when the whole mora overlaps. We felt that the observation of the sizable (although not significant) 16-ms difference between overlap and control prime in the MOPE part induced the necessity of testing the romaji targets again, though this time with hiragana primes (thereby eliminating any processing costs due to script unfamiliarity).

Table 3
Mean Naming Latencies (in Ms) and Error Rates (in %) in Experiment 2 as a Function of Target Type (Hiragana vs. Romaji), Prime Type (MOPE vs. MORA), and Relatedness (Overlap vs. Control)

	Hiragana target				Romaji target			
	MOPE prime		MORA prime		MOPE prime		MORA prime	
Condition	RT (*SD*)	Error rate	RT (*SD*)	Error rate	RT (*SD*)	Error rate	RT (*SD*)	Error rate
Control	527 (76)	0.8	521 (87)	0.0	753 (123)	3.2	765 (132)	2.4
Overlap	530 (89)	0.8	525 (75)	0.8	737 (110)	1.6	732 (134)	0.8
Effect	−3	0.0	−4	−0.8	16 (83)	1.6	33	1.6

Note. MOPE = masked onset priming effect; MORA = mora overlap; RT = reaction time; *SD* = standard deviation.

Experiment 3: Effect of Hiragana Primes on Romaji Targets

Experiment 2 showed that romaji targets take longer to read than hiragana targets. No effect was found for any hiragana target combined with romaji primes (which also took longer), but again a MORA and not a MOPE effect was found when romaji targets were used. In this third experiment we aimed to replicate and extend these findings by again using romaji targets, thus again allowing the response to dictate the unit of speech planning (phonemes). However, current primes were all in hiragana, which allows for a comparison between fast access (Experiment 3) and slow access (Experiment 2) to the prime.

Method

Participants. Thirty-one undergraduate students from Nagoya University (16 female, 15 male; average age = 22 years, *SD* = 3.7) took part in this experiment in exchange for financial compensation. All participants were native speakers (and fluent readers) of Japanese and had normal or corrected-to-normal vision.

Stimuli. Forty-two bi-moraic words were selected from the same pool as in Experiment 2 (see Appendix B). In this experiment, all targets were in romaji (letters) and all primes were in hiragana.

Design. A 2 (prime type: MOPE or MORA) × 2 (relatedness: overlap vs. control) within-subjects factorial design was implemented. Recurrent repetition of targets and primes was avoided by presenting each participant with two repetitions instead of four per target, equaling 84 trials per participant. Each participant received two blocks of 42 trials, encompassing all 42 targets once per block. Participants were assigned to pseudo-random lists (generated per participant). These were constructed such that MORA and MOPE conditions appeared equally often per group and phonologically or semantically related primes or targets had at least a distance of two trials. Between participants the design included all the experimental conditions, and within participants the order of blocks was counterbalanced.

Procedure. The procedure was the same as in Experiment 2.

Results

Naming latencies exceeding three standard deviations per participant per condition and voice-key errors were excluded from the analysis (1.3% of the data). As errors were few (2.2% of the data) and were evenly distributed across conditions, an error analysis was not performed. See Table 4 for an overview of the results. There was no main effect of prime type (MOPE or MORA), $F_1(1, 30) = 1.24$, $MSE = 933.20$, $p = .274$; $F_2(1, 41) = 1.33$, $MSE = 815.20$, $p = .256$; min $F'(1, 68) < 1$, but there was a main effect of relatedness (overlap vs. control). Targets preceded by overlapping primes were read on average 11 ms faster than those preceded by control primes, $F_1(1, 30) = 5.75$, $MSE = 653.30$, $p < .05$; $F_2(1, 41) = 5.12$, $MSE = 1{,}439.90$, $p < .05$; min $F'(1, 70) = 2.71$, $p = .10$. To explore this further, we performed paired *t* tests and found that MOPE primes again did not supply reliable priming effects, $t_1(30) = 1.52$, $SD = 42.00$, $p = .139$; $t_2(41) = 1.46$, $SD = 50.30$, $p = .153$, but MORA overlapping primes yielded facilitation effects in comparison to their control primes (33 ms), $t_1(30) = 3.92$, $SD = 47.59$, $p < .001$; $t_2(41) = 4.48$, $SD = 54.77$, $p < .001$.

Table 4
Mean Naming Latencies (in Ms) and Error Rates (in %) in Experiment 3 on the Romaji Targets as a Function of Prime Type (MOPE/MORA) and Relatedness (Overlap and Control)

Condition	MOPE prime RT (*SD*)	MOPE prime Error rate	MORA prime RT (*SD*)	MORA prime Error rate
Control	733 (98)	2.0	761 (104)	2.4
Overlap	744 (110)	1.6	728 (107)	2.8
Priming effect	−11	0.4	33	−0.4

Note. MOPE = masked onset priming effect; MORA = mora overlap; RT = reaction time; *SD* = standard deviation.

Discussion

This experiment yielded essentially the same results as Experiment 2: MOPE primes do not induce a significant facilitation effect. The results from Experiments 2 and 3 indicate that even when romaji script is used to present the prime (thereby favoring segmental processing), the functional unit of phonological encoding in Japanese is likely to be the mora, as evidenced by the significant CV but not C priming effects reported in the previous three experiments. However, two main issues remained to be addressed: (a) the script change issue of Experiment 1 (MORA: katakana primes and hiragana targets) and (b) the fact that in most stimuli of Experiments 1–3 moras were indistinguishable from syllables (e.g., こと/ko.to/).

Experiment 4a: Distinguishing the CV From the Syllable: MOPE Group

A possible reason for the discrepancy between the MOPE and MORA groups in Experiment 1 might be that in the MORA group there was a script change (from katakana to hiragana), whereas in the MOPE group this change was absent. We remedied this in Experiments 4a and 4b by using katakana primes and hiragana targets in both the MOPE and MORA groups. However, a more important issue may be the fact that in most stimuli we used in the previous experiments the mora was indistinguishable from the syllable. For instance, the moras /ko/ and /to/ in こと /ko.to/ constitute two moras but also two syllables. Therefore, in Experiment 4, we included three groups of target words. In the first group, bi-moraic words (where mora equals syllable) were used. In the second and third groups, the first CV does not constitute the whole syllable: nasal coda words (CVN; e.g., /hoN.da/ "Honda" [CVN.CV]; Group 2) and geminate obstruents, (CVQ; e.g., /saQ.ka/ "soccer" [CVQ.CV]; Group 3). As previous experiments never showed any sign of onset priming in Japanese, we expected that Experiment 4a (which employed only onset overlap primes) would not show priming in any of the groups. Furthermore, with regard to Experiment 4b, we predicted that if the functional unit in Japanese is the mora, we would obtain CV priming effects in all three groups, without an interaction between group and relatedness, as the priming effect should be similar between groups. In contrast, we expected that when the previously observed priming effects were in fact due to syllabic overlap, CV priming would occur only in the bi-moraic group and not the nasal coda and geminate groups.

Method

Participants. Twenty-seven undergraduate students from Yamaguchi University (21 female, 6 male; average age = 22 years, *SD* = 7.5) took part in this experiment in exchange for financial compensation. All participants were native speakers of Japanese and had normal or corrected-to-normal vision.

Stimuli. Forty-two bi-moraic words were selected for each group, totaling 126 targets (see Appendix C). Targets were all in hiragana and primes, were all in katakana. Congruent prime–target pairs were combined such that they overlapped in the onset (MOPE).

Design. A 3 (group: bi-moraic, nasal coda, and geminate) × 2 (relatedness: overlap vs. control) within-subjects factorial design was implemented. To avoid recurrent repetition of targets and primes, we subjected each participant to one repetition instead of two per target, equaling 126 trials per participant. Each participant was subjected to two blocks of 63 trials (groups were mixed in blocks). Participants were assigned to pseudo-random lists (generated per participant), which were constructed such that groups and conditions appeared approximately equally often per block and phonologically or semantically related primes or targets had at least a distance of two trials. Between participants, the design included all the groups and experimental conditions, and within participants the order of blocks was counterbalanced.

Procedure. The procedure was the same as in Experiment 2. Masks, primes, and targets were displayed in Courier New font (36 pt). All items appeared as black characters on white background. Each target word covered approximately 1.3° of visual angle from a viewing distance of 60 cm. Target words were between two and five hiragana characters in length, subtending between 1.9° and 4.7° of visual angle.

Results and Discussion

Table 5 provides an overview of the results. Naming latencies exceeding three standard deviations per participant per condition and voice-key errors were excluded from the analysis (5.1% of the data). As errors were few (0.5% of the data), an error analysis was not performed. There was a significant main effect of group, $F_1(2, 52) = 7.50$, $MSE = 1{,}178.16$, $p < .001$; $F_2(2, 123) = 4.60$, $MSE = 2{,}653.40$, $p < .05$; min $F'(2, 169) = 2.85$, $p = .06$, reflecting the fact that the bi-moraic targets were named faster than the nasal coda and geminate targets, which did not differ from each other. There was no main effect of relatedness in the subjects analysis, $F_1(1, 26) = 1.70$, $MSE = 678.80$, $p = .203$, but it was significant in the items analysis, $F_2(1, 123) = 6.60$, $MSE = 468.20$, $p < .05$; min $F'(1, 41) = 1.35$, $p = .25$. The interaction between group and relatedness was not significant (*F*s < 1). Planned *t* tests showed that there was no reliable effect of overlap for any group: bi-mora, *t*s < 1; nasal coda, $t_1 < 1$, $t_2(41) = 1.4$, $SD = 30.14$, $p = .169$; and geminate, $t_1 < 1$; $t_2(41) = 1.97$, $SD = 34.23$, $p = .056$. Overall, there seems to be no reliable effect of segment overlap on group level when only the segment overlaps.

Experiment 4b: Distinguishing the CV From the Syllable: MORA Group

Method

Participants. Twenty-eight undergraduate students from Nagoya University (12 female, 16 male; average age = 19 years, *SD* = 3.3) took part in this experiment in exchange for financial compensation. All participants were native speakers of Japanese and had normal or corrected-to-normal vision.

Stimuli. Thirty bi-moraic words were selected for each group, totaling 90 targets (see Appendix C). All targets were in hiragana, and all primes were in katakana. Congruent prime–target pairs were combined such that they had CV (mora) overlap.

Design. A 3 (group: bi-moraic, nasal coda, and geminate) × 2 (relatedness: overlap vs. control) within-subjects factorial design was implemented. To avoid recurrent repetition of targets and primes, we subjected each participant to one repetition instead of two per target, equaling 90 trials per participant. Each participant was subjected to two blocks of 45 trials (groups were mixed in a block). Participants were assigned to pseudo-random lists (generated per participant), which were constructed such that groups and conditions appeared approximately equally often per block and phonologically or semantically related primes or targets had at least a distance of two trials. Between participants the design included all the groups and experimental conditions, and within participants the order of blocks was counterbalanced.

Procedure. The procedure was the same as in Experiment 4a.

Results and Discussion

Table 6 gives an overview of the results. Naming latencies exceeding three standard deviations per participant per condition

Table 5
Mean Naming Latencies (in Ms) and Error Rates (in %) in Experiment 4a as a Function of Group (Bi-Moraic, Nasal Coda, and Geminate) and Relatedness (Overlap and Control)

	Bi-moraic		Nasal coda		Geminate	
Condition	RT (*SD*)	Error rate	RT (*SD*)	Error rate	RT (*SD*)	Error rate
Control	527 (69)	0.6	552 (92)	0.6	545 (78)	0.0
Overlap	522 (66)	0.0	547 (93)	1.2	539 (84)	0.6
Priming effect	5	0.6	5	−0.6	6	−0.6

Note. RT = reaction time; *SD* = standard deviation.

Table 6
Mean Naming Latencies (in Ms) and Error Rates (in %) in Experiment 4b as a Function of Group (Bi-Moraic, Nasal Coda, and Geminate) and Relatedness (Overlap vs. Control)

	Bi-moraic		Nasal coda		Geminate	
Condition	RT (*SD*)	Error rate	RT (*SD*)	Error rate	RT (*SD*)	Error rate
Control	471 (61)	0.0	501 (74)	2.4	489 (69)	0.6
Overlap	456 (68)	0.0	490 (77)	1.8	477 (72)	0.0
Priming effect	15	0.0	11	0.6	12	0.6

Note. RT = reaction time; *SD* = standard deviation.

and voice-key errors were excluded from the analysis (2.2% of the data). As errors were few (0.8 % of the data), an error analysis was not performed. There was a main effect of group, $F_1(2, 54) = 38.50$, $MSE = 365.46$, $p < .001$; $F_2(2, 87) = 12.20$, $MSE = 1{,}212.64$, $p < .001$; min $F'(2, 130) = 9.26$, $p < .001$, which reflects significant differences in the overall means of the three groups. Furthermore, there was a main effect of relatedness (overlap vs. control), $F_1(1, 27) = 24.10$, $MSE = 279.70$, $p < .001$; $F_2(1, 87) = 17.20$, $MSE = 379.24$, $p < .001$; min $F'(1, 97) = 10.04$, $p < .001$, reflecting the fact that on average targets that overlapped with the prime were named 13 ms faster. Most important, there was no interaction between group and relatedness (*F*s < 1), indicating that the effect of relatedness holds for all target groups. This was further confirmed by planned *t* tests, which showed that the effect of overlap held for each group: bi-mora, $t_1(27) = 3.05$, $SD = 25.93$, $p < .01$; $t_2(29) = 2.86$, $SD = 27.45$, $p < .01$; nasal coda, $t_1(27) = 2.54$, $SD = 22.72$, $p < .05$; $t_2(29) = 2.30$; $SD = 23.34$, $p < .05$; and geminate, $t_1(27) = 3.07$, $SD = 20.95$, $p < .01$; $t_2(29) = 2.10$, $SD = 31.26$, $p < .05$.

Before accepting the conclusion that the mora and not the phoneme is the functional unit of language production in Japanese, we consider three points. The first point is that the conclusion that there is no MOPE in Japanese corresponds to the null hypothesis. Of course, conventional significance testing cannot state the evidence in favor of a null hypothesis: Nonsignificant *p* values indicate "failures to reject" the null hypothesis, not the support of it. However, recent developments in the Bayesian data analysis technique (e.g., Dienes, 2008; Rouder, Speckman, Sun, & Morey, 2009) have contributed to the interpretation of null results in the form of computation of the Bayes factor. The Bayes factor is generally interpreted as the weight of evidence provided by the data and is essentially an odds ratio, ranging between 0 to infinity. A Bayes factor of 1 means that the data provide equal evidence in support of the null and alternative hypotheses. Values greater than 1 favor the null hypothesis, and values less than 1 favor the alternative hypothesis. According to Jeffreys' (1961) classification scheme, a Bayes factor between 1 and 3 would constitute anecdotal evidence for the null hypothesis, one between 3 and 10 would be substantial evidence, and one between 10 and 30 would be strong evidence.

Although we are aware that the use of Bayes factors is not firmly established in psycholinguistic literature, we do feel that in this case it is reasonable to report them as we specifically claim the absence of onset priming (and not merely a reduction). We therefore computed the Bayes factor for the null hypothesis (i.e., that there is no MOPE) for each experiment, using the Bayes factor calculator provided by Rouder et al. (2009; available at http://pcl.missouri.edu/bayesfactor). Bayes factors based on the Jeffreys–Zellner–Siow priors (recommended by Rouder et al. as a "default Bayes factor" requiring minimal assumptions) are presented in Table 7. As effect sizes for the MOPE are generally small, we used a scaled factor according to the effect size for MOPE calculated from Kinoshita (2000; Experiment 2) of $r = .58$ instead of the standard $r = 1$. According to Rouder et al. (2009, p. 233), this is acceptable when small effect sizes are expected.

As shown in Table 7, in all cases (except for the items factor in the geminate part of Experiment 4), the Bayes factor favored the null hypothesis, with the evidence approaching or surpassing "substantial" in many cases. We therefore include these Bayes factor values in our argument that most of our data indicate that there is no MOPE in Japanese.

The second point is that we might not have obtained onset priming in Japanese due to a lack of power. As the onset priming effect might be small and hard to detect in Japanese, we pooled all MOPE data from our experiments (separately for hiragana and romaji targets).[2] On these pooled data, we performed a repeated-measures analysis of variance with relatedness (overlap, control) as a within-subjects factor and experiment (1, 2, 4 [for hiragana targets] and 2, 3 [for romaji targets]) as a between-subjects and between-items factor.

For the hiragana targets (with the three groups for Experiment 4 pooled together), there was no main effect of relatedness (*F*s < 1) or experiment (in the subjects analysis), $F_1 < 1$, $F_2(1, 123) = 3.80$, $MSE = 1{,}647.42$, $p = .03$. Nor was there an interaction between relatedness and experiment, $F_1 < 1$; $F_2(2, 123) = 1.02$, $MSE = 513.13$, $p = .363$.

For the romaji targets, there was no main effect of relatedness (*F*s < 1) or experiment (*F*s < 1); nor was there an interaction with experiment, $F_1(1, 69) = 2.95$, $MSE = 2{,}316.82$, $p = .090$; $F_2(1, 82) = 1.66$, $MSE = 3{,}731.78$, $p = .201$; min $F'(1, 145) = 1.06$, $p = .304$. Therefore, increasing power by pooling the data for onset related stimuli (MOPE parts) did not lead to reliable priming effects, either.

A third point worth mentioning (which was also raised in the introduction and for Experiment 1) is that the moraic nature of the kana script used in Experiments 4a and 4b might favor the processing from orthography to phonology. Although we cannot unequivocally refute the claim that the use of kana script has been responsible for the obtained pattern of effects, we do believe that

[2] We thank an anonymous reviewer for suggesting this analysis to us.

Table 7
Bayes Factor Values for the Null Hypothesis for MOPE (Scaled JNZ Factor With r *= .58)*

Experiment and condition	Subjects	Items
Experiment 1	3.68	4.34
Experiment 2		
Hiragana target	4.42	4.92
Romaji target	2.41	3.86
Experiment 3	1.62	1.93
Experiment 4		
Bi-mora	2.75	3.24
Nasal coda	3.36	2.08
Geminate	3.35	0.91

Note. MOPE = masked onset priming effect; JNZ = Jeffreys–Zellner–Siow.

our Experiments 2 and 3 reasonably demonstrated that when romanized Japanese (romaji) targets are employed, no reliable priming occurs for the segment.

General Discussion

Many studies using different paradigms have shown that the segment (e.g., phoneme) can be conceived of as an independent functional element of speech production planning in many alphabetic languages (e.g., implicit priming/preparation effect: Meyer, 1991; masked onset priming effect: Forster & Davis, 1991; Kinoshita, 2003; Schiller, 2004). Studies investigating other nonalphabetic languages have found that this unit might be language specific. In Mandarin Chinese, for example, segment preparation was absent but syllable priming was present (Chen et al., 2002). For our target language, Japanese, contrasting patterns were reported in comprehension tasks (Cutler & Otake, 1994; Otake & Cutler, 2003), and there is currently only one empirical paper to be found regarding production tasks (Kureta et al., 2006). Our aim in the present research was to further examine a possible role for the segment as independent functional unit in Japanese speech production by making use of the well-established masked priming paradigm.

The outcomes of four experiments support previous findings obtained by Kureta et al. (2006), who proposed that the mora and not the segment is the functional unit of phonological encoding in Japanese. Introducing romaji stimuli, which by their visual characteristics were assumed to favor segmental processing (our Experiments 2 and 3), also did not lead to onset priming. This indicates that the observed absence of onset priming (e.g., our findings and those of Kureta et al., 2006) cannot have been due to the fact that kana and/or kanji scripts were used. We ruled out the possibility that the absence of MOPE was due to the nature of target script governing the unit of phonological encoding, as presenting the target in romaji (in which the orthography-to-phonology mapping process proceeds by letter-to-segment) did not produce MOPE.

It is important to note that each mora contains more phonological content than a phoneme. Consider, for instance, results by Schiller (2004), who found that when two segments overlap, more priming is obtained. For instance, /ba/ produced more priming than /b/ when naming the word *BALLET* (“ballet”), but /br/ also produced more priming than /b/ for a complex onset word such as *BROEDER* (“brother”).[3] That is, the finding of MORA priming but not MOPE may simply reflect a greater amount of phonological overlap, not the special status of the mora as a functional unit of language production in Japanese. An experiment in which the amount of initial phonemic overlap is increased without increasing the number of mora is needed to test this. Unfortunately, this is not easy to realize in Japanese, due the absence of consonant clusters. The closest match to such an experiment would be the inclusion of the palatal glide (denoted j), which is occasionally situated between particular initial consonants and their subsequent vowels. In that case, the initial Cj cluster—for instance, /ky/ of a word such as /kyu.u/ (CjV.R) “sudden, haste”; two moras, namely, /kyu/ (CjV) and a long vowel (R)—would contain more phonological content than the phoneme /k/ in a CV mora structure such as /ku/ does. This has thus far not been tested with the masked priming paradigm; however, Kureta et al. (2006; Experiment 2) specifically tested this possibility using the preparation paradigm. They did not find significant preparation effects even when an additional segment (i.e., palatal glide) was added to the prevocalic consonant, which favors the hypothesis that the mora is the functional unit in Japanese speech production. Still, additional masked onset priming experiments using Cj initial overlap might be warranted to provide information as to whether the absence of the greater overlap (as found by Kureta et al., 2006) also generalizes to masked priming.

A recent proposal considering functional unit size (O’Seaghdha, Chen, & Chen, 2010) puts forward a new term called the *proximate units principle*. In short, they proposed that “proximate units (PU) are the first selectable phonological units below the level of the word/morpheme” (O’Seaghdha et al., 2010, p. 285). They additionally put forward that languages may differ in their specific proximate unit sizes. In Dutch and English the PU would be the segment, in Chinese it would be the syllable (Chen et al., 2002), whereas in Japanese the PU would be the mora (Kureta et al., 2006, and our current findings). One can infer from this proposal that across-language comparisons might also show different types of speech errors. For instance, Japanese speakers may be less prone to make phoneme exchange errors (e.g., spoonerisms), as their proximate unit is larger (e.g., a mora). Indeed, evidence provided by Kubozono (1989) shows that in Japanese most speech errors occur at mora, not segment or syllable, boundaries. An interesting question (for further examination) then arises regarding how bilingual speakers of languages differing in proximate unit (e.g., Japanese and English) encode the functional unit of their second language. Would, for instance, Japanese/English versus English/Japanese bilinguals show diverging results on masked and implicit priming tasks, or could the proximate unit be switched depending on the language in use? Yet another possibility might be even the transfer of the proximate unit from, for example, the first to the second language, depending on the task at hand.

In conclusion, in line with those of Kureta et al. (2006), our results corroborate the view that, in Japanese, moras and not segments or syllables are the functional (or proximate) units. That

[3] Note, however, that the increase in priming due to an additional overlapping phoneme beyond the onset (e.g., /sif-SIB/ vs. /suf-SIB/) is small and may not be significant (e.g., Kinoshita, 2000; Mousikou, Coltheart, & Saunders, 2010).

is, they are the units that play a crucial role in the construction of the phonological form of a word in speech production.

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Appendix A

Stimulus Materials From Experiment 1

	MOPE part		MORA part	
Target	Onset prime	Control prime	Overlap prime	Control prime
かぜ “kaze”	こと “koto”	そと “soto”		
きく “kiku”	くら “kura”	むら “mura”		
くに “kuni”	かみ “kami”	なみ “nami”	クイ “kui”	ルイ “rui”
けさ “kesa”	きか “kika”	びか “bika”	ケツ “ketsu”	ネツ “netsu”
こま “koma”	けつ “ketsu”	ねつ “netsu”	コト “koto”	ソト “soto”
さら “sara”	しか “shika”	ちか “chika”	サメ “same”	マメ “mame”
しき “shiki”	さめ “same”	まめ “mame”	シカ “shika”	チカ “chika”
すし “sushi”	せん “sen”	れん “ren”	スミ “sumi”	グミ “gumi”
せき “seki”	そと “soto”	こと “koto”		
そふ “sofu”	すみ “sumi”	ぐみ “gumi”	ソト “soto”	コト “koto”
まど “mado”	めい “mei”	べい “bei”	マメ “mame”	サメ “same”
みみ “mimi”	まめ “mame”	さめ “same”	ミコ “miko”	ヒコ “hiko”
むし “mushi”	もり “mori”	のり “nori”		
めし “meshi”	むら “mura”	くら “kura”	メイ “mei”	ゲイ “gei”
もち “mochi”	みこ “miko”	ひこ “hiko”		
なつ “natsu”	のり “nori”	もり “mori”	ナミ “nami”	タミ “tami”
にわ “niwa”	ぬか “nuka”	ぶか “buka”	ニク “niku”	リク “riku”
ぬま “numa”	ねつ “netsu”	けつ “ketsu”	ヌカ “nuka”	ブカ “buka”
ねこ “neko”	なみ “nami”	かみ “kami”	ネツ “netsu”	ケツ “ketsu”
のど “nodo”	にく “niku”	りく “riku”	ノリ “nori”	モリ “mori”
らく “raku”	るり “ruri”	くり “kuri”		
りか “rika”	れん “ren”	せん “sen”		
るす “rusu”	りく “riku”	にく “niku”	ルイ “rui”	クイ “kui”
れつ “retsu”	ろく “roku”	ほく “hoku”		
ろじ “roji”	らち “rachi”	さち “sachi”	ロク “roku”	ホク “hoku”
たけ “take”	てき “teki”	へき “heki”	タミ “tami”	ナミ “nami”
てつ “tetsu”	とみ “tomi”	ごみ “gomi”	テキ “teki”	ヘキ “heki”
とり “tori”	たく “taku”	がく “gaku”	トミ “tomi”	ゴミ “gomi”
はな “hana”	ほく “hoku”	ろく “roku”	ハラ “hara”	バラ “bara”
ひふ “hifu”	はら “hara”	ばら “bara”	ヒコ “hiko”	ミコ “miko”
へび “hebi”	ひこ “hiko”	みこ “miko”		
ほり “hori”	へい “hei”	?げい “gei”	ホク “hoku”	ロク “roku”
ばつ “batsu”	ぼし “boshi”	とし “toshi”	バラ “bara”	ハラ “hara”
びわ “biwa”	ばら “bara”	はら “hara”	ビカ “bika”	キカ “kika”
ぶた “buta”	びか “bika”	きか “kika”	ブカ “buka”	ヌカ “nuka”
べつ “betsu”	ぶか “buka”	ぬか “nuka”		
ぼく “boku”	べい “bei”	めい “mei”	ボシ “boshi”	トシ “toshi”
がか “gaka”	ぎむ “gimu”	じむ “jimu”		
ぎし “gishi”	ぐみ “gumi”	すみ “sumi”		
ぐち “guchi”	がく “gaku”	たく “taku”	グミ “gumi”	スミ “sumi”
げき “geki”	ごみ “gomi”	とみ “tomi”	ゲイ “gei”	メイ “mei”
ごご “gogo”	げい “gei”	へい “hei”	ゴミ “gomi”	トミ “tomi”

Note. MOPE = masked onset priming effect; MORA = mora overlap.

(*Appendices continue*)

Appendix B

Stimulus Materials From Experiments 2 and 3

	MOPE part		MORA part	
Target	Onset prime	Control prime	Overlap prime	Control prime
かぜ "kaze"	こと "koto"	そと "soto"	かみ "kami"	なみ "nami"
きく "kiku"	くら "kura"	むら "mura"	きか "kika"	びか "bika"
くに "kuni"	かみ "kami"	なみ "nami"	くら "kura"	むら "mura"
けさ "kesa"	きか "kika"	びか "bika"	けつ "ketsu"	ねつ "netsu"
こま "koma"	けつ "ketsu"	ねつ "netsu"	こと "koto"	そと "soto"
さら "sara"	しか "shika"	ちか "chika"	さめ "same"	まめ "mame"
しき "shiki"	さめ "same"	まめ "mame"	しか "shika"	ちか "chika"
すし "sushi"	せん "sen"	れん "ren"	すみ "sumi"	ぐみ "gumi"
せき "seki"	そと "soto"	こと "koto"	せん "sen"	れん "ren"
そふ "sofu"	すみ "sumi"	ぐみ "gumi"	そと "soto"	こと "koto"
まど "mado"	めい "mei"	べい "bei"	まめ "mame"	さめ "same"
みみ "mimi"	まめ "mame"	さめ "same"	みこ "miko"	ひこ "hiko"
むし "mushi"	もり "mori"	のり "nori"	むら "mura"	くら "kura"
めし "meshi"	むら "mura"	くら "kura"	めい "mei"	べい "bei"
もち "mochi"	みこ "miko"	ひこ "hiko"	もり "mori"	のり "nori"
なつ "natsu"	のり "nori"	もり "mori"	なみ "nami"	かみ "kami"
にわ "niwa"	ぬか "nuka"	ぶか "buka"	にく "niku"	りく "riku"
ぬま "numa"	ねつ "netsu"	けつ "ketsu"	ぬか "nuka"	ぶか "buka"
ねこ "neko"	なみ "nami"	かみ "kami"	ねつ "netsu"	けつ "ketsu"
のど "nodo"	にく "niku"	りく "riku"	のり "nori"	もり "mori"
らく "raku"	るり "ruri"	くり "kuri"	らち "rachi"	さち "sachi"
りか "rika"	れん "ren"	せん "sen"	りく "riku"	にく "niku"
るす "rusu"	りく "riku"	にく "niku"	るり "ruri"	くり "kuri"
れつ "retsu"	ろく "roku"	ほく "hoku"	れん "ren"	せん "sen"
ろじ "roji"	らち "rachi"	さち "sachi"	ろく "roku"	ほく "hoku"
たけ "take"	てき "teki"	へき "heki"	たく "taku"	がく "gaku"
てつ "tetsu"	とみ "tomi"	ごみ "gomi"	てき "teki"	へき "heki"
とり "tori"	たく "taku"	がく "gaku"	とみ "tomi"	ごみ "gomi"
はな "hana"	ほく "hoku"	ろく "roku"	はら "hara"	ばら "bara"
ひふ "hifu"	はら "hara"	ばら "bara"	ひこ "hiko"	みこ "miko"
へび "hebi"	ひこ "hiko"	みこ "miko"	へい "hei"	げい "gei"
ほり "hori"	へい "hei"	げい "gei"	ほく "hoku"	ろく "roku"
ばつ "batsu"	ぼし "boshi"	とし "toshi"	ばら "bara"	はら "hara"
びわ "biwa"	ばら "bara"	はら "hara"	びか "bika"	きか "kika"
ぶた "buta"	びか "bika"	きか "kika"	ぶか "buka"	ぬか "nuka"
べつ "betsu"	ぶか "buka"	ぬか "nuka"	べい "bei"	めい "mei"
ぼく "boku"	べい "bei"	めい "mei"	ぼし "boshi"	とし "toshi"
がか "gaka"	ぎむ "gimu"	じむ "jimu"	がく "gaku"	たく "taku"
ぎし "gishi"	ぐみ "gumi"	すみ "sumi"	ぎむ "gimu"	じむ "jimu"
ぐち "guchi"	がく "gaku"	たく "taku"	ぐみ "gumi"	すみ "sumi"
げき "geki"	ごみ "gomi"	とみ "tomi"	げい "gei"	へい "hei"
ほり "gogo"	げい "gei"	へい "hei"	ごみ "gomi"	とみ "tomi"

Note. MOPE = masked onset priming effect; MORA = mora overlap.

(*Appendices continue*)

Appendix C

Stimulus Materials From Experiments 4a and 4b

	MOPE part (4a)		MORA part (4b)	
Target	Onset prime	Control prime	Overlap prime	Control prime
かぜ “kaze”	コト “koto”	ソト “soto”		
きく “kiku”	クラ “kura”	ムラ “mura”		
くに “kuni”	カミ “kami”	ナミ “nami”	クイ “kui”	ルイ “rui”
けさ “kesa”	キカ “kika”	ビカ “bika”	ケツ “ketsu”	ネツ “netsu”
こま “koma”	ケツ “ketsu”	ネツ “netsu”	コト “koto”	ソト “soto”
さら “sara”	シカ “shika”	チカ “chika”	サメ “same”	マメ “mame”
しき “shiki”	サメ “same”	マメ “mame”	シカ “shika”	チカ “chika”
すし “sushi”	セン “sen”	レン “ren”	スミ “sumi”	グミ “gumi”
せき “seki”	ソト “soto”	コト “koto”		
そふ “sofu”	スミ “sumi”	グミ “gumi”	ソト “soto”	コト “koto”
まど “mado”	メイ “mei”	ベイ “bei”	マメ “mame”	サメ “same”
みみ “mimi”	マメ “mame”	サメ “same”	ミコ “miko”	ヒコ “hiko”
むし “mushi”	モリ “mori”	ノリ “nori”		
めし “meshi”	ムラ “mura”	クラ “kura”	メイ “mei”	ゲイ “gei”
もち “mochi”	ミコ “miko”	ヒコ “hiko”		
なつ “natsu”	ノリ “nori”	モリ “mori”	ナミ “nami”	タミ “tami”
にわ “niwa”	ヌカ “nuka”	ブカ “buka”	ニク “niku”	リク “riku”
ぬま “numa”	ネツ “netsu”	ケツ “ketsu”	ヌカ “nuka”	ブカ “buka”
ねこ “neko”	ナミ “nami”	カミ “kami”	ネツ “netsu”	ケツ “ketsu”
のど “nodo”	ニク “niku”	リク “riku”	ノリ “nori”	モリ “mori”
らく “raku”	ルリ “ruri”	クリ “kuri”		
りか “rika”	レン “ren”	セン “sen”		
るす “rusu”	リク “riku”	ニク “niku”	ルイ “rui”	クイ “kui”
れつ “retsu”	ロク “roku”	ホク “hoku”		
ろじ “roji”	ラチ “rachi”	サチ “sachi”	ロク “roku”	ホク “hoku”
たけ “take”	テキ “teki”	ヘキ “heki”	タミ “tami”	ナミ “nami”
てつ “tetsu”	トミ “tomi”	ゴミ “gomi”	テキ “teki”	ヘキ “heki”
とり “tori”	タク “taku”	ガク “gaku”	トミ “tomi”	ゴミ “gomi”
はな “hana”	ホク “hoku”	ロク “roku”	ハラ “hara”	バラ “bara”
ひふ “hifu”	ハラ “hara”	バラ “bara”	ヒコ “hiko”	ミコ “miko”
へび “hebi”	ヒコ “hiko”	ミコ “miko”		
ほり “hori”	ヘイ “hei”	ゲイ “gei”	ホク “hoku”	ロク “roku”
ばつ “batsu”	ボシ “boshi”	トシ “toshi”	バラ “bara”	ハラ “hara”
びわ “biwa”	バラ “bara”	ハラ “hara”	ビカ “bika”	キカ “kika”
ぶた “buta”	ビカ “bika”	キカ “kika”	ブカ “buka”	ヌカ “nuka”
べつ “betsu”	ブカ “buka”	ヌカ “nuka”		
ぼく “boku”	ベイ “bei”	メイ “mei”	ボシ “boshi”	トシ “toshi”
がか “gaka”	ギム “gimu”	ジム “jimu”		
ぎし “gishi”	グミ “gumi”	スミ “sumi”		
ぐち “guchi”	ガク “gaku”	タク “taku”	グミ “gumi”	スミ “sumi”
げき “geki”	ゴミ “gomi”	トミ “tomi”	ゲイ “gei”	メイ “mei”
ごご “gogo”	ゲイ “gei”	ヘイ “hei”	ゴミ “gomi”	トミ “tomi”
かんじ “kanji”	コト “koto”	ソト “soto”		
きんし “kinshi”	クラ “kura”	ムラ “mura”		
くんし “kunshi”	カミ “kami”	ナミ “nami”	クイ “kui”	ルイ “rui”
けんか “kenka”	キカ “kika”	ビカ “bika”	ケツ “ketsu”	ネツ “netsu”
こんど “kondo”	ケツ “ketsu”	ネツ “netsu”	コト “koto”	ソト “soto”
さんそ “sanso”	シカ “shika”	チカ “chika”	サメ “same”	マメ “mame”
しんか “shinka”	サメ “same”	マメ “mame”	シカ “shika”	チカ “chika”
すんか “sunka”	セン “sen”	レン “ren”	スミ “sumi”	グミ “gumi”
せんし “senshi”	ソト “soto”	コト “koto”		
そんけい “sonkei”	スミ “sumi”	グミ “gumi”	ソト “soto”	コト “koto”
まんが “manga”	メイ “mei”	ベイ “bei”	マメ “mame”	サメ “same”
みんわ “minwa”	マメ “mame”	サメ “same”	ミコ “miko”	ヒコ “hiko”

(*Appendices continue*)

Appendix C (*continued*)

	MOPE part (4a)		MORA part (4b)	
Target	Onset prime	Control prime	Overlap prime	Control prime
むんず "munzu"	モリ "mori"	ノリ "nori"		
めんきょ "menkyo"	ムラ "mura"	クラ "kura"	メイ "mei"	ゲイ "gei"
もんく "monku"	ミコ "miko"	ヒコ "hiko"		
なんばん "nanban"	ノリ "nori"	モリ "mori"	ナミ "nami"	タミ "tami"
にんき "ninki"	ヌカ "nuka"	ブカ "buka"	ニク "niku"	リク "riku"
ぬんちゃく "nunchaku"	ネツ "netsu"	ケツ "ketsu"	ヌカ "nuka"	ブカ "buka"
ねんど "nendo"	ナミ "nami"	カミ "kami"	ネツ "netsu"	ほく "ketsu"
のんき "nonki"	ニク "niku"	リク "vriku"	ノリ "nori"	モリ "mori"
らんし "ranshi"	ルリ "ruri"	クリ "kuri"		
りんじ "rinji"	レン "ren"	セン "sen"		
るんば "runba"	リク "riku"	ニク "niku"	ルイ "rui"	クイ "kui"
れんが "renga"	ロク "roku"	ホク "hoku"		
ろんぎ "rongi"	ラチ "rachi"	サチ "sachi"	ロク "roku"	ホク "hoku"
たんご "tango"	テキ "teki"	ヘキ "heki"	タミ "tami"	ナミ "nami"
てんし "tenshi"	トミ "tomi"	ゴミ "gomi"	テキ "teki"	ヘキ "heki"
とんぼ "tonbo"	タク "taku"	ガク "gaku"	トミ "tomi"	ゴミ "gomi"
はんこ "hanko"	ホク "hoku"	ロク "roku"	ハラ "hara"	バラ "bara"
ひんど "hindo"	ハラ "hara"	バラ "bara"	ヒコ "hiko"	ミコ "miko"
へんか "henka"	ヒコ "hiko"	ミコ "miko"		
ほにゃ "honya"	ヘイ "hei"	ゲイ "gei"	ホク "hoku"	ロク "roku"
ばんち "banchi"	ボシ "boshi"	トシ "toshi"	バラ "bara"	ハラ "hara"
びんせん "binsen"	バラ "bara"	ハラ "hara"	ビカ "bika"	キカ "kika"
ぶにゃ "bunya"	ビカ "bika"	キカ "kika"	ブカ "buka"	ヌカ "nuka"
べんり "benri"	ブカ "buka"	ヌカ "nuka"		
ぼんち "bonchi"	ベイ "bei"	メイ "mei"	ボシ "boshi"	トシ "toshi"
がんそ "ganso"	ギム "gimu"	ジム "jimu"		
ぎんか "ginka"	グミ "gumi"	スミ "sumi"		
ぐんじ "gunji"	ガク "gaku"	タク "taku"	グミ "gumi"	スミ "sumi"
げんし "genshi"	ゴミ "gomi"	トミ "tomi"	ゲイ "gei"	メイ "mei"
ごんげ "gonge"	ゲイ "gei"	ヘイ "hei"	ゴミ "gomi"	トミ "tomi"
かっき "kakki"	コト "koto"	ソト "soto"		
きっぷ "kippu"	クラ "kura"	ムラ "mura"		
くっしん "kusshin"	カミ "kami"	ナミ "nami"	クイ "kui"	ルイ "rui"
けっか "kekka"	キカ "kika"	ビカ "bika"	ケツ "ketsu"	ネツ "netsu"
こっき "kokki"	ケツ "ketsu"	ネツ "netsu"	コト "koto"	ソト "soto"
さっか "sakka"	シカ "shika"	チカ "chika"	サメ "same"	マメ "mame"
しっぽ "shippo"	サメ "same"	マメ "mame"	シカ "shika"	チカ "chika"
すっきり "sukkiri"	セン "sen"	レン "ren"	スミ "sumi"	グミ "gumi"
せっし "sesshi"	ソト "soto"	コト "koto"		
そっき "sokki"	スミ "sumi"	グミ "gumi"	ソト "soto"	コト "koto"
まっちゃ "maccha"	メイ "mei"	ベイ "bei"	マメ "mame"	サメ "same"
みっつ "mittsu"	マメ "mame"	サメ "same"	ミコ "miko"	ヒコ "hiko"
むっつ "muttsu"	モリ "mori"	ノリ "nori"		
めっき "mekki"	ムラ "mura"	クラ "kura"	メイ "mei"	ゲイ "gei"
もっか "mokka"	ミコ "miko"	ヒコ "hiko"		
なっとう "nattou"	ノリ "nori"	モリ "mori"	ナミ "nami"	タミ "tami"
にっき "nikki"	ヌカ "nuka"	ブカ "buka"	ニク "niku"	リク "riku"
ぬっと "nutto"	ネツ "netsu"	ケツ "ketsu"	ヌカ "nuka"	ブカ "buka"
ねっき "nekki"	ナミ "nami"	カミ "kami"	ネツ "netsu"	ケツ "ketsu"
のっとり "nottori"	ニク "niku"	リク "riku"	ノリ "nori"	モリ "mori"
らっか "rakka"	ルリ "ruri"	クリ "kuri"		

(*Appendices continue*)

Appendix C (*continued*)

Target	MOPE part (4a)		MORA part (4b)	
	Onset prime	Control prime	Overlap prime	Control prime
りっぱ "rippa"	レン "ren"	セン "sen"		
るっくす "rukkusu"	リク "riku"	ニク "niku"	ルイ "rui"	クイ "kui"
れっとう "rettou"	ロク "roku"	ホク "hoku"		
ろっぷ "roppu"	ラチ "rachi"	サチ "sachi"	ロク "roku"	ホク "hoku"
たった "tatta"	テキ "teki"	ヘキ "heki"	タミ "tami"	ナミ "nami"
てっぽう "teppou"	トミ "tomi"	ゴミ "gomi"	テキ "teki"	ヘキ "heki"
とって "totte"	タク "taku"	ガク "gaku"	トミ "tomi"	ゴミ "gomi"
はっぱ "happa"	ホク "hoku"	ロク "roku"	ハラ "hara"	バラ "bara"
ひっこし "hikkoshi"	ハラ "hara"	バラ "bara"	ヒコ "hiko"	ミコ "miko"
へっつい "hettsui"	ヒコ "hiko"	ミコ "miko"		
ほっと "hotto"	ヘイ "hei"	ゲイ "gei"	ホク "hoku"	ロク "roku"
ばった "batta"	ボシ "boshi"	トシ "toshi"	バラ "bara"	ハラ "hara"
びっくり "bikkuri"	バラ "bara"	ハラ "hara"	ビカ "bika"	キカ "kika"
ぶっし "busshi"	ビカ "bika"	キカ "kika"	ブカ "buka"	ヌカ "nuka"
べっそう "bessou"	ブカ "buka"	ヌカ "nuka"		
ぼっちゃん "bocchan"	ベイ "bei"	メイ "mei"	ボシ "boshi"	トシ "toshi"
がっき "gakki"	ギム "gimu"	ジム "jimu"		
ぎっしり "gisshiri"	グミ "gumi"	スミ "sumi"		
ぐったり "guttari"	ガク "gaku"	タク "taku"	グミ "gumi"	スミ "sumi"
げっぷ "geppu"	ゴミ "gomi"	トミ "tomi"	ゲイ "gei"	メイ "mei"
ごっかん "gokkan"	ゲイ "gei"	ヘイ "hei"	ゴミ "gomi"	トミ "tomi"

Note. MOPE = masked onset priming effect; MORA = mora overlap.

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