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The functional phonological unit of Japanese-English bilinguals is language dependent: Evidence from masked onset and mora priming effects[1]

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Abstract: Speech production research has shown that Japanese monolingual speakers use mora-sized phonological units, not phoneme-sized units, when phonologically encoding Japanese words. Recent bilingual research has indicated that proficient Japanese-English bilinguals nevertheless use phoneme-sized units when phonologically encoding English words, suggesting that use of a phonological unit that is smaller than that of their L1 develops with increasing proficiency in English. The purpose of the present research was to determine whether proficient Japanese-English bilinguals also begin to use the smaller, phoneme-sized units when producing Japanese words. In a masked priming naming task, proficient Japanese-English bilinguals produced a significant masked onset priming effect for English words, confirming that they do use phoneme-sized units when phonologically encoding in English (L2). These bilinguals, however, showed only mora-based facilitation for Japanese words in an experiment involving only Japanese words. These results suggest that proficient bilinguals use different unit sizes depending on the language being produced, and that for bilinguals whose L1 and L2 have different unit sizes, the phonological encoding process is at least somewhat different in their two languages.

Key words: masked onset and mora priming effect, Japanese-English bilinguals, phonological unit-size, speech production, phonological encoding.

When one speaks, representations of to-be-spoken words are first accessed in the speaker's mental lexicon, and then the phonological properties of the words are retrieved and encoded before the articulation system initiates the actual act of speaking. According to Levelt, Roelofs, and Meyer (1999), the phonological encoding process occurs incrementally from word beginning to word ending by assigning phonemes to metrical frames, in which the syllable and stress patterns are specified. The information is then sent to the articulatory system for execution of motor movements. The assignment of phonemes into a metrical frame is called the segment-to-frame association process, and is the essential step for successful word production.

The first empirical evidence that the phoneme is the unit used in the phonological encoding process was presented by Meyer (1991) using an "implicit priming" paradigm with Dutch stimuli. In these experiments, participants first learned a small set of semantically related word pairs (e.g., hour-time, swim-pool,

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ground-soccer). The first words served as prompts with the second words being the correct responses to those prompts. In the experiment itself, participants were simply asked to produce the response word upon presentation of the prompt word. Prompt-response pairs were grouped together so that in one condition all of the response words shared their initial onset (e.g., time, tone, tennis) and in another condition, none of the response words shared their initial onset (e.g., time, pool, soccer). In response to the prompts, response words were produced significantly faster when all words shared their onset than when they did not. In contrast, when all the response words shared rhymes (e.g., murder, ponder, boulder), no such advantage occurred. The faster response for the onset-related response words is called the preparation effect, and is assumed to occur because the phonological representation of the onset is prepared and buffered due to the fact that it is entirely predictable, facilitating subsequent production of the word. The finding that there is no advantage for the rhyme shared response words is consistent with the assumption that phonological encoding occurs incrementally from the beginning of a word to the end. Phonemes at the end of the word can be prepared only after the beginning of a word has been phonologically encoded.

Support for the idea that the phoneme is the unit in the phonological encoding process also comes from studies using a masked priming naming task (see Kinoshita, 2003 for a review). In this paradigm, participants are asked to read aloud a target as fast and accurately as possible. Targets are preceded by the brief presentation of a prime (e.g., 50 ms) which is not visible to participants. In this situation, targets are named significantly faster when a prime shares an onset phoneme with the target (hark-HEEL) than when it does not (pork-HEEL) (e.g., Forster & Davis, 1991; Kinoshita, 2000a; Malouf & Kinoshita, 2007; Schiller, 2004). Paralleling the results in Meyer's (1991) implicit priming paradigm, naming latencies are not any faster when a prime shares a rhyme with its target than in an unrelated control condition (e.g., Kinoshita, 2000a; Schiller, 2004). In addition, prime-target pairs sharing a beginning phoneme but not sharing a beginning grapheme (e.g., kite-CAGE) produce a facilitation effect (Kinoshita, 2000b; Timmer & Schiller, 2012), while prime-target pairs sharing a beginning grapheme but not sharing a beginning phoneme (e.g., cement-CONGRESS) do not (Schiller, 2007; Timmer & Schiller, 2012), indicating that the locus of the priming effect is phonological, rather than orthographic. The significant facilitation effect for prime-target pairs sharing an onset phoneme is known as the masked onset priming effect, and is consistent with both the idea that phonological encoding is executed incrementally from word beginning to word ending, and the idea that the phoneme is the unit used in the segment-to-frame association process.

Much of the empirical support for the assumption that the phoneme is the unit used in the phonological encoding process has, however, come from studies using Indo-European languages such as English and Dutch. In contrast, recent research suggests that the phonological unit used to fill in the metrical frame is different in other types of languages. For example, Chen, Chen, and Dell (2002), using the implicit priming paradigm, revealed that in Mandarin Chinese, the production of response words is not facilitated when response words share their initial phoneme. Instead, the authors found that it is only when response words share their initial syllable that the production of Chinese words is facilitated (see also O'Seaghdha, Chen, & Chen, 2010). Similarly, Kureta, Fushimi, and Tatsumi (2006), also using the implicit priming paradigm, found that in Japanese, it is not when response words share their initial phoneme (e.g., かつら/katsura/, くじら/kujira/, 古墳/kofun/), but when the words share their initial mora (e.g., かつら/katsura/, 歌舞伎/kabuki/, 鞄/kaban/), that the production of Japanese words is facilitated.

Complimentary to the findings of Kureta et al. (2006), Verdonschot et al. (2011), using a masked priming naming task with Japanese, found a significant facilitatory priming effect when targets were primed by words sharing their initial mora (e.g., サメ/same/ - さら/sara/) relative to control primes (マメ/mame/ -さら/sara/), but did not find such an effect when targets were primed by words sharing only their initial phoneme (e.g., カミ/kami/ - くに/kuni/) relative to control primes (ナミ/nami/ - くに/kuni/). Further, Verdonschot et al. showed that this effect is not dependent on the script in which the Japanese words are written, as it is found using both kana, a mora-based script (i.e., each character normally corresponds to a mora), as well as romaji, which is an alphabetic script (i.e., each character normally corresponds to a phoneme). Likewise, the syllabic based facilitation for Mandarin Chinese speakers is also observed with picture and speech stimuli (Chen & Chen, 2013), which also suggests that the effect is not driven by the script of the stimulus. These results, therefore, suggest that the phonological unit used in speech production is the syllable in Mandarin Chinese and is the mora in Japanese.

All the speech production research discussed above, investigating the nature of the phonological unit, has involved monolingual participants. An obvious question is, of course, what are the implications for the nature of the phonological unit when one becomes bilingual, particularly when the normally-used phonological units in those two languages are different? Recent speech production research with bilinguals suggests two conclusions. First, for bilinguals whose phonological unit appears to be the phoneme in both languages, the phonological encoding process occurs similarly in the two languages (Timmer & Schiller, 2012), and, in fact, the phonological encoding process is most likely shared across languages (Roelofs, 2003). Second, for bilinguals whose phonological units appear to be different in their two languages, such as Chinese-English bilinguals whose L1 phonological unit appears to be the syllable (Chen et al., 2002; Chen & Chen, 2013; O'Seaghdha et al., 2010), and Japanese-English bilinguals whose L1 phonological unit appears to be the mora (Kureta et al., 2006; Verdonschot et al., 2011), the phonological unit used in English word production, nonetheless, still appears to be the phoneme.

This second conclusion was initially advanced by Verdonschot, Nakayama, Zhang, Tamaoka, and Schiller (2013) based on data from the masked priming naming task. In their study, proficient Chinese-English bilinguals named English targets significantly faster when the targets were primed by a word sharing an onset relative to control primes (e.g., bark-BENCH vs. dark-BENCH), just as the native English speakers do. Similarly, using the same task and the same stimulus materials but with slightly different procedures, Nakayama, Verdonschot, Ida, and Kinoshita (2014) also showed that proficient Japanese-English bilinguals (average Test of English for International Communication (TOEIC) score = 876) produced a significant masked onset priming effect to English targets (i.e., BENCH is named faster when primed by bark than by dark), again suggesting that these bilinguals use the phoneme as their phonological unit in the production of English words. The proficient Japanese-English and Chinese-English bilinguals also showed a facilitation effect for targets primed by initial CV (mora) related words (bell-BENCH) relative to an unrelated control condition (cell-BENCH), an expected outcome when prime-target pairs share their initial phoneme and more.

Nakayama et al. (2014) also suggested that the use of phoneme-based phonological encoding for English words must be a behavior that develops with increasing proficiency in English. This suggestion was supported by their finding that less proficient Japanese-English bilinguals (average TOEIC score = 715) did not show a masked onset priming effect. The less proficient bilinguals, showed a significant facilitation effect only when English targets were primed by CV (mora)-related words (i.e., BENCH is named faster when primed by bell than by cell). The essential conclusion is that, although Japanese-English bilinguals may initially use a mora-sized unit when producing English words, with increased proficiency in English, it is replaced by a phoneme-sized unit. The more general conclusion, based on the results of both Verdonschot et al. (2013), with Chinese-English bilinguals and Nakayama et al. (2014) with Japanese-English bilinguals, is that bilinguals whose two languages have different phonological unit sizes do acquire an appropriately sized phonological unit for speaking in their L2 as they become more proficient in that second language.

The present research concerned a potential consequence of the acquisition of the phoneme-sized unit by Japanese-English bilinguals on their production of Japanese (i.e., L1) words. The question asked was whether there would be some evidence of use of a phoneme-sized unit by proficient Japanese-English bilinguals when producing Japanese words. On the one hand, it is possible that once these individuals have learned to use phoneme-sized units, their default unit would shift to the smaller unit and this unit would be used regardless of the language being produced. Roelofs (2003) suggested that the phonological encoding process is shared for bilinguals whose phonological unit in their two languages is the phoneme, presumably because doing so allows an economic use of resources. If proficient Japanese-English bilinguals do develop a system involving shared phonological encoding, they may start to rely on phoneme-sized units, which means that they may show a phoneme-based facilitation effect even with Japanese stimuli. On the other hand, it is also possible that the size of the phonological unit used by bilinguals completely depends on the language being spoken at the moment, as it may actually be more economical to use a unit that is most suitable for that language. If so, then proficient bilinguals should show phoneme-based facilitation in English, and only mora-based facilitation in Japanese.

Verdonschot et al. (2013) did address this question with Chinese-English bilinguals; however, their experiments yielded inconclusive results. When their Chinese-English bilinguals, who showed a significant onset priming effect with English stimuli, were presented with Chinese stimuli in the same experimental session, significant phoneme-based facilitation was observed when the prime-target had the same syllabic structure (e.g., naming of 贫/pin2/ was faster when primed by 盘/pan2/ than by 民/min2/). However, no such effect was observed for prime-target words that had different syllabic structures (naming of 贫/pin2/ was not any faster when primed by 爬/pa2/ than by 迷/mi2/). The significant onset priming effect with Chinese stimuli for the same-syllabic structure prime-target pairs suggests that proficient Chinese-English bilinguals do use a phoneme-sized unit in Chinese production. However, the lack of an onset priming effect with the other half of their stimuli would support the opposite conclusion. While further research is needed in order to understand the impact of syllable structure, what is important with regard to the present research is that the results of Verdonschot et al. do not give a clear answer to the question of whether proficient Chinese-English bilinguals' default phonological unit shifts to the phoneme in L1 word production.

In the present Experiment 1, proficient Japanese-English bilinguals named both English and Japanese words. For each language, targets were primed by words sharing onsets (e.g., bark-BENCH, and kizu-KAKUGO) or by unrelated control primes (e.g., dark-BENCH, and mizu-KAKUGO). The same targets were also primed by words sharing initial morae (bell-BENCH, and kami-KAKUGO) or by unrelated control primes (cell-BENCH, and tami-KAKUGO). Based on Nakayama et al. (2014), who observed a significant masked onset priming effect in English with their proficient Japanese-English bilinguals, we expected to replicate that effect with our proficient bilinguals, which, to anticipate that important component of our results, did occur. Thus, the critical question was whether these proficient bilinguals, who have acquired use of phoneme-size units, would also show phoneme-based facilitation for Japanese words.

Experiment 1

In Experiment 1, the same set of English stimuli as used in Verdonschot et al. (2013) was used. Japanese stimuli were newly selected. The Japanese stimuli were presented in romaji script. Although Verdonschot et al. (2011) demonstrated that script type does not modulate priming effects with Japanese monolinguals, it seemed possible that any phoneme-based facilitation in Japanese may be easier to observe for Japanese-English bilinguals when Japanese targets are presented in the same script as the English targets.

Method

Participants. Thirty-six Japanese-English bilingual students from Waseda University participated in this experiment. Their average TOEIC score was 866 (range = 800–965, maximum score = 990). Participants received ¥1000 for their participation.

Stimuli. For the English stimuli, the same set of English materials as used in Verdonschot et al. (2013) was used. Targets were 42 English words ($M = 50.3$ occurrences per million, Kućera & Francis, 1967). The targets were on average 4.5 letters long (range = 4.0–5.0). For each target (e.g., BENCH), four types of primes were selected: Onset related (e.g., bark), Onset control (e.g., dark), Mora related (e.g., bell), and Mora control (e.g., cell). These primes had comparable mean frequencies (52.8, 59.4, 58.2, and 50.9, respectively) and word lengths (3.6, 3.6, 3.8, and 3.8).

For the Japanese stimuli, the targets were 42 Japanese words transcribed into romaji script. The original targets were three morae multiple-character Kanji words with a normative frequency of 22.2 occurrences per million (Amano & Kondo, 2003).[2] The transcribed targets were on average 6.5 letters long (range = 6.0–7.0). As in the English prime-target condition, for each target (KAKUGO), four types of primes were selected: Onset related (e.g., kizu), Onset control (e.g., mizu), Mora related (e.g., kabe), and Mora control (e.g., nabe). Primes were two-morae Japanese words that were also transcribed into romaji. As romaji is rarely used in daily life, there is not any corpus or database of word characteristics. Therefore, it was not possible to control for word frequency across the four types of prime words. Because masked onset priming effects appear to be unaffected by stimulus frequency or lexicality (e.g., Dimitropoulou, Duñabeitia, & Carreiras, 2010; Kinoshita, 2000a; Malouf & Kinoshita, 2007; Verdonschot et al., 2011), this aspect of our design should not have affected the nature of the priming effects. Lastly, all of the Japanese prime-target pairs had the same onset syllabic structure (i.e., CV-CV), although there is little evidence that syllabic structure is relevant to onset/mora-priming effects with Japanese stimuli (see Verdonschot et al., 2011, Experiment 4).

Procedure. Each participant was tested individually in a normally lit room. The DMDX software package (Forster & Forster, 2003) was used for stimulus presentation and data collection. Each trial started with a forward mask (#####) presented in the center of the screen, which was followed by the prime in lower case presented for 50 ms. The prime was immediately replaced by a target in upper case, which remained until participants made a response. Participants were instructed to read aloud the target as quickly and accurately as possible. There were 12 practice trials, none of which involved any of the experimental stimuli, before the experimental trials.

The presentation of stimulus language was blocked: half of the participants received the English stimuli first and then received the Japanese stimuli, and the other half received the Japanese stimuli first and then received the English stimuli. Within each language block, the same set of 42 targets was presented twice, once in the Onset condition and once in the Mora condition. Half of the participants were presented with the Onset condition first and the other half were presented with the Mora condition first. Targets primed by related primes in the Onset condition were primed by control primes in the Mora condition, and vice versa. Therefore, within each language block, there were two counterbalancing lists with regard to prime-target relationships (i.e., critical vs. control), but there were four presentation lists

[2]Normative frequencies were based on the NTT database (Amano & Kondo, 2003), which provides frequency counts based on a corpus of 287,792,797 words. The normative frequencies reported here are per million words, created by dividing the original frequencies by 287.8.

Table 1 Experiment 1: Mean naming latencies (in ms) and percentage errors for English targets and Japanese romaji targets primed by onset primes, onset control primes, mora primes, and mora control primes

	Onset condition		Mora condition	
	Example	RT (errors)	Example	RT (errors)
English Targets				
Related prime	bark-BENCH	594 (2.5%)	bell-BENCH	576 (1.6%)
Unrelated prime	dark-BENCH	601 (2.9%)	cell-BENCH	600 (3.6%)
Priming effect	–	7** (0.4%)	–	24*** (2.0%)
Japanese Targets				
Related prime	kizu-KAKUGO	750 (3.6%)	kami-KAKUGO	752 (3.6%)
Unrelated prime	mizu-KAKUGO	750 (5.7%)	tami-KAKUGO	771 (2.6%)
Priming effect		0 (2.1%*)		19** (–1.1%)

Note. RT = response time.
*$p < .05$. **$p < .01$. ***$p < .001$.

due to the alteration of the presentation order of the Onset and Mora conditions (the Onset condition first then Mora condition, or the Mora condition first then the Onset condition).

Results

Participants' responses were checked using Check Vocal Software (Protopapas, 2007). Extremely short and long correct responses were removed as outliers (shorter than 250 ms and longer than 1500 ms in the English block and shorter than 250 ms and longer than 1800 ms in the Japanese romaji block). This data treatment removed 0.5% of the data in the English block and 0.9% of the data in the Japanese block. The remainder of the data were analyzed using linear mixed model analysis with the lme4 package in R (Baayen, 2008; Bates, Maechler, & Bolker, 2012). In this analysis, the raw response times (RT) are transformed to −1000/RT to reduce the skewness in the distribution while keeping the direction of effects. The *p*-value was estimated using a Markov Chain Monte Carlo procedure sampling method with10,000 iterations. Table 1 shows the mean word naming latencies and error rates for English and Japanese romaji targets.

English targets. For the English stimuli, analyses were conducted identically to those of Nakayama et al. (2014). That is, the Onset condition and Mora condition were analyzed separately, with Prime Type (related vs. control) and Presentation Order of Onset condition (first or second) and their interaction as fixed factors and subjects and items as random factors. The interaction between Prime Type and the Presentation Order was included to make sure that the repeated presentation of the same set of targets did not modulate the pattern of priming effects. The following target lexical characteristics that were entered by Nakayama et al. were also entered into the model: word length (Length), log-transformed word frequency (Log frequency), and orthographic neighborhood size (Ortho-N). Lastly, the participants' TOEIC score was also entered in the model. For each of the Onset and Mora conditions, the final model used in the analysis was [inverseRT – PrimeType × Order + TOEIC score + Length + Log frequency + Ortho-N + (1 | subject) + (1 | item)]. The initial analysis revealed that the presentation order of Onset and Mora condition did not modulate the overall pattern of priming effect for the Onset condition ($t = 0.68$, $p = .49$) or for the Mora condition ($t = –0.49$, $p = .62$). In addition, the inclusion of the interaction term did not significantly improve the model fit of the data (*ps* > .40). Therefore the interaction term was removed from the model. Lastly, error analyses did not reveal any significant priming effects; thus for the English block only the results of the latency analysis are reported.

In the Onset condition, naming latencies were significantly faster when the targets were presented for the second time than the first time ($t = -1.68$, $p = .01$). Response latencies were significantly faster when the English targets were primed by onset related words relative to the control condition ($t = -2.59$, $p = .01$), replicating the findings of Nakayama et al. (2014). There was a 7 ms masked onset priming effect, an effect size that falls within the typical range of 5–16 ms (e.g., Dimitropoulou et al., 2010; Kinoshita, 2000a; Kinoshita & Woollams, 2002; Schiller, 2007). In the Mora condition, naming latencies were also significantly faster when the targets were presented for the second than the first time ($t = -4.50$, $p < .001$). As expected, response latencies were significantly faster when the targets were primed by mora related words relative to the control condition ($t = -6.88$, $p < .001$), showing a strong 24 ms mora priming effect.

In both Onset and Mora conditions, higher TOEIC scores were associated with shorter naming latencies to English targets, ($t = -2.26$, $p < .01$ and $t = -2.85$, $p < .001$, respectively). The effects of target lexical characteristics were also similar in the Onset and Mora conditions: shorter naming latencies were associated with higher log frequency ($t = -2.92$, $p < .001$ and $t = -3.41$, $p < .001$), and higher number of orthographic neighbors ($t = -1.68$, $p = .05$ and $t = -2.18$, $p < .01$). In both conditions, there was no effect of target word length (i.e., $t = -1.37$, $p > .10$ and $t = -1.34$, $p > .10$).

Romaji-transcribed Japanese targets. The data for Japanese targets were analyzed similarly to the English target data. We entered the following lexical characteristics of romaji-transcribed Japanese targets in the model: letter length (Length) and log word frequency of the original Kanji compound words (Log frequency). Thus, in the Japanese romaji condition, the model used in the analysis was [inverseRT – PrimeType × Order + TOEIC score + Length + Log Frequency + (1 | subject) + (1 | item)]. Similar to the English target block, in both the Onset and Mora conditions, the interaction between PrimeType and Presentation Order was not significant (ps > .50). Similarly, the inclusion of the interaction term did not improve the model fit, (all ps > .50). Therefore, this term was removed from the model.

In the Onset condition, the effect of Presentation Order was marginally significant ($t = -1.31$, $p = .08$), with shorter naming latencies in the second than in the first presentation. Critically, there was no onset priming effect: targets primed by onset-related words were not named faster than targets in the unrelated condition ($t = 0.47$, $p = .65$). In the Mora condition, naming latencies were significantly shorter in the second presentation than in the first presentation ($t = -4.45$, $p < .001$). Unlike the Onset condition, targets primed by mora-related words were named significantly faster than those in the control condition ($t = 2.59$, $p = .01$; a 19 ms mora priming effect).

Interestingly, for both the Onset and Mora conditions, higher TOEIC scores were associated with shorter naming latencies to romaji-transcribed Japanese words ($t = -1.70$, $p = .02$ and $t = 2.38$, $p = .002$), indicating that higher TOEIC scores were associated with faster processing of romaji (alphabet) script. The effect of the target frequency of the original Kanji words was not significant in either condition ($t = -0.79$, $p > .10$, and $t = -1.07$, $p > .10$), suggesting that the targets were named without accessing the lexical representations of the original Kanji words. The effect of target length was also not significant in both conditions ($t = 1.00$, $p > .10$ and $t = 1.01$, $p > .10$). Lastly, for the error analysis, there was a significant priming effect in the Onset condition ($z = 1.97$, $p = .05$). Targets preceded by onset-related primes were named slightly more accurately (3.6%) than targets preceded by unrelated primes (5.7%). No other effects were significant in the analyses of errors.

Discussion

When English words were presented as targets, naming latencies were significantly faster when those targets were preceded by words sharing onset phonemes than by control primes, producing a 7 ms masked onset priming effect. Our proficient bilinguals also produced a significant

24 ms mora priming effect. These results closely replicated the results of Nakayama et al. (2014), who observed a 14 ms masked onset priming effect and a 22 ms mora priming effect. The significant masked onset priming effect observed in Experiment 1 supports the conclusion that proficient Japanese-English bilinguals use phoneme units when producing English words.

The critical question being asked in the present research was which phonological unit (i.e., phoneme or mora) is used when proficient bilinguals produce Japanese words. Our latency results showed that romaji Japanese targets were not facilitated by onset-related primes relative to control primes. It was only when the Japanese targets were preceded by mora-related primes that significant facilitation was observed. The results in the onset-related condition with Japanese romaji targets, therefore, indicate that the phonological unit used in producing Japanese words is the mora, not the phoneme, even when the individuals being tested are proficient in English. That is, based on the present results, it appears that bilinguals use the phoneme when producing English words, and use the mora when producing Japanese words, meaning that bilinguals adjust their phonological units depending on the language they are using.

Such an interpretation may be slightly premature, however, because our error rate analysis revealed a significant onset-based priming effect for Japanese targets. That is, although no overall onset priming effect in the Japanese latency data suggests that the mora is the phonological unit used in Japanese word production, the Japanese error data provided at least some suggestion that phonemes were used as phonological units in Japanese as well as English. Therefore, there is still some ambiguity concerning our Japanese results with respect to whether the phoneme plays a role when proficient bilinguals produce Japanese words.

Experiment 2

The results of Experiment 1 confirmed that proficient Japanese-English bilinguals do acquire the phoneme-sized unit when producing English words. However, the results with Japanese romaji stimuli did not give a conclusive answer to our critical question of what phonological unit is used by Japanese-English bilinguals when speaking in Japanese.

As noted, with Chinese-English bilinguals, Verdonschot et al. (2013) also reported some evidence of an onset priming effect with L1 Chinese targets, which was confined to prime-target pairs that had the same onset syllable structures (i.e., CV-CV or CVN-CVN). Verdonschot et al. (2013) suggested that the significant onset-priming effect with Chinese targets could have been caused by the presence of the English block that was included in the same experimental session. Similarly, in the present Experiment 1, English and Japanese target blocks were presented in the same experimental session. If bilinguals whose phonological units were different in L1 and L2 really do normally use different phonological units when speaking L1 versus L2, our experimental setup may have made it difficult to clearly demonstrate that fact. That is, the presence of the English block may have artificially biased readers toward a phoneme strategy even when reading Japanese.

A straightforward way to resolve this potential problem would be to run another experiment in which only Japanese stimuli are presented. In Experiment 2, 33 of the 36 proficient bilinguals who participated in Experiment 1 returned to the lab in order to name Japanese targets only. In Experiment 2, the Japanese romaji stimuli used in Experiment 1 were presented in the more visually familiar kana script. The kana script was chosen so that overall naming error rates would be reduced (as the significant onset priming effect was apparent only in the error data in Experiment 1) and also all vestiges of an English context would be removed. Based on the results of Verdonschot et al. (2011), script type (romaji vs. kana) should not influence the nature of the underlying phonological unit size when Japanese words are produced.

Method

Participants. Thirty-three Japanese-English bilingual students participated in Experiment 2.

Table 2 Experiment 2: Mean naming latencies (in ms) and percentage errors for kana targets primed by onset primes, onset control primes, mora primes, and mora control primes

	Onset condition		Mora condition	
	Example	RT (errors)	Example	RT (errors)
Related prime	キズーかくご	494 (1.7%)	カミーかくご	470 (0.7%)
Unrelated prime	ミズーかくご	494 (1.6%)	タミーかくご	478 (2.0%)
Priming effect		0 (–0.1%)		8*** (1.3%)

Note. RT = response time.
***$p < .001$.

All 33 of them had participated in Experiment 1. For each individual, there was at least a 2-week interval between the two experiments. The average TOEIC score of the bilinguals was 867 (range = 805–965). Participants received ¥1000 for their participation.

Stimuli. The same Japanese stimuli used in Experiment 1 were used in Experiment 2. In this experiment, those stimuli were presented in kana script. To reduce orthographic overlap between the prime and target, the targets were presented in Hiragana and the primes were presented in Katakana. The targets were all three characters in length and the primes were all two characters in length.

Procedure. The procedure was the same as in Experiment 1 except that this time bilinguals were presented with Japanese stimuli only.

Results

Extremely short (<250 ms) and long (> 1500 ms) correct responses were removed as outliers (0.11% of the data). The remaining data were analyzed identically to the analysis for the Japanese stimuli in Experiment 1, except that target length was not included as a factor because all targets had three characters. Thus, the model used in this analysis was [inverseRT – PrimeType × Order + TOEIC score + Log Frequency + (1 | subject) + (1 | item)]. Once again, the interaction was removed after confirming that the presentation order of the Onset and Mora condition did not affect the pattern of priming effects and did not improve the model fit of the data (all ps > .45). Table 2 shows the mean word naming latencies and error rates for Japanese kana targets. As can be seen in Table 2, the overall error rates were now very small ($M = 1.5\%$).

In the Onset condition, targets were named faster in the second than in the first presentation ($t = -1.71$, $p = .06$). Replicating the results of Experiment 1, targets primed by onset related primes were not named any faster than targets in the control condition ($t = 1.26$, $p > .20$). In the Mora condition, targets were named significantly faster in their second presentation ($t = -1.85$, $p < .01$). Targets primed by mora related primes were named significantly faster than targets in the control condition ($t = 3.66$, $p < .001$), showing an 8 ms mora priming effect. In both the Onset and Mora conditions, the TOEIC score did not account for significant variance in the data (both ts < 1), an expected outcome when bilinguals are presented with L1 stimuli. In addition, the effect of target frequency was also not significant in either condition (both ts < 1), again suggesting that the targets were named without accessing the lexical representations of the original Kanji words. In the analyses of errors, none of the effects was statistically significant; most importantly, there was no evidence of an onset priming effect (error rates of 1.7% and 1.6%, in the onset and control conditions, respectively). In the Mora condition, there was a trend toward facilitation (error rates of 0.7% and 2.0% in the mora and control conditions, respectively), but this difference was not statistically significant ($z = 1.64$, $p = .099$).

Discussion

The results of Experiment 2 were straightforward. When proficient bilinguals named Japanese targets only there was significant mora-based facilitation but there was no hint of phoneme-based facilitation. Because these proficient bilinguals were the same as those who showed significant phoneme-based facilitation with English words, these results indicated that bilinguals do adjust their phonological unit depending on the language that is being produced.[3] That is, the phonological unit normally used by Japanese-English bilinguals in phonological encoding is the mora for Japanese words and the phoneme for English words.

General discussion

Previous studies in speech production have showed that the phonological unit used by Japanese monolinguals is the mora (Kureta et al., 2006; Verdonschot et al., 2011). Recently, Nakayama et al. (2014) showed that proficient Japanese-English bilinguals, but not less proficient bilinguals, use phoneme-sized units in producing English words. These results indicate that, with increased proficiency in English, Japanese-English bilinguals engage a new phonological unit that is smaller than that of their L1.[4] The present research concerned the phonological unit of Japanese-English bilinguals in L1 speech production.

The specific question asked in the present research was which phonological unit, the phoneme or the mora, would be used when proficient Japanese-English bilinguals produce Japanese words. In Experiment 1, our Japanese-English bilinguals produced a significant onset priming effect with English stimuli, replicating the findings reported in Nakayama et al. (2014), confirming that our proficient Japanese-English bilinguals did use phoneme-sized units in English speech production.

When Japanese stimuli (presented in an alphabetic (romaji) script) were presented in the same experimental session as English stimuli in Experiment 1, the bilinguals did not show an overall onset priming effect for Japanese stimuli in the latency data, showing only mora-based facilitation. At the same time, however, they showed a small but significant phoneme-based facilitation on error rates. The significant masked onset priming effect on errors suggests that these bilinguals may benefit from phoneme-based overlap even in L1 speech production. We proposed that a likely reason for this small effect on error rates appears to be that the experimental setup created an English context. Because proficient bilinguals have acquired the ability to use phoneme-size units in their phonological processing, it may be possible for them to be induced to use those smaller units to some degree, even when producing words in languages like Japanese and Chinese. That is, evidence for some use of phoneme-based processing may manifest itself in L1 production under the situation where the phoneme-sized unit is activated by the experimental context, as may have occurred in the present Experiment 1 and in Verdonschot et al. (2013) testing Chinese-English bilinguals.

Consistent with this idea, in Experiment 2, when only Japanese words, written in kana script, were presented the same bilinguals showed no hint of phoneme-based facilitation, while showing reliable mora-based facilitation. These results suggest that at least in normal reading, Japanese-English bilinguals do not use phoneme-sized units, but use mora-sized units when producing Japanese words. In other words, the unit of phonological encoding is not the same across a bilingual's two languages

[3]The data pattern in Experiment 1 did not change when the data from three bilinguals who did not return to participate in Experiment 2 were removed.

[4]Our post hoc analyses of Experiment 1 revealed that the English onset priming effect was not related to bilinguals' TOEIC scores ($p > .10$). Instead, a significant relationship was found between the onset priming effect and the months our subjects spent abroad ($p < .001$). These two findings were, in fact, consistent with what Nakayama et al. (2014) found in their experiments. These results suggest that the development of phoneme-size units appears to be more directly affected by other factors that codevelop with better L2 proficiency, such as better phonological awareness of English words.

when the optimal unit sizes for the two languages do differ.

One may wonder, however, if the lack of an onset-priming effect in Experiment 2 may have been influenced by the use of mora-based kana script. Such a conclusion seems unlikely, as Verdonschot et al. (2011) found that when Japanese speakers produced Japanese words, they always used mora-sized units, but never phoneme-sized units, whether the stimuli were presented in romaji (phoneme-based characters) or kana (mora-based characters). This result clearly suggests that script type does not affect the nature of the underlying phonological unit used in speech production. However, given the previous discussion, if it is true that the Roman script used in Experiment 1 was a strong enough cue to trigger some use of a phoneme-based strategy, the use of romaji script may also be sufficient to produce some evidence of a significant onset priming effect for proficient Japanese-English bilinguals. The fact that we did not observe any onset priming effect with kana-only stimuli in Experiment 2 means that such an effect with romaji, if it really did exist, would merely indicate that proficient Japanese-English bilinguals can adopt a phoneme-based strategy even when producing Japanese. We should also note, however, that the complete lack of an onset priming effect in the Japanese response latency data in Experiment 1, despite the experimental context encouraging the use of a phoneme-sized unit, suggests that the impact of script must be quite minor.[5]

The results of the present research suggest that proficient Japanese-English bilinguals use mora-sized units when producing Japanese words and phoneme-sized units when producing English words. However, the investigation of speech production in bilinguals, particularly bilinguals whose two unit sizes are different, is still in its infancy. The conclusion of the present research will be further reinforced when the same conclusion has been derived from studies using different experimental paradigms and/or using nonlinguistic materials such as pictures. What will also be interesting to determine, assuming that Japanese-English bilinguals truly can be induced to switch toward more of a phoneme-based process in their L1 by the nature of the experimental context, is what aspects of that context produce such a switch and to what extent that ability is affected by proficiency in English.

[5]Subsequently, we conducted an additional masked priming experiment that confirmed this suggestion. In that experiment, 40 proficient Japanese-English bilinguals, matched in L2 proficiency to those used in the present experiments (average TOEIC score = 871), received only the romaji stimuli used in Experiment 1. As expected, there was a significant 8 ms mora priming effect ($t = 2.13$, $p < .05$). Critically, there was no onset priming effect for response latencies ($t = 0.70$, $p > .40$) or for errors ($z = 0.30$, $p > .70$).

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