THE QUARTERLY JOURNAL OF EXPERIMENTAL PSYCHOLOGY, 2013
Vol. 66, No. 10, 2023–2038, http://dx.doi.org/10.1080/17470218.2013.773050

Routledge
Taylor & Francis Group

The multiple pronunciations of Japanese kanji: A masked priming investigation

Rinus Gerardus Verdonschot[1,2,3], Wido La Heij[3], Katsuo Tamaoka[1], Sachiko Kiyama[4], Wen-Ping You[5], and Niels Olaf Schiller[2,3]

[1]Graduate School of Languages and Cultures, Nagoya University, Nagoya, Japan
[2]Leiden Institute for Brain and Cognition & Leiden University Centre for Linguistics, Leiden University, Leiden, The Netherlands
[3]Cognitive Psychology Unit and Leiden Institute for Brain and Cognition, Leiden University, Leiden, The Netherlands
[4]Functional Brain Imaging Laboratory, Department of Gerontechnology, National Center for Geriatrics and Gerontology, Ohbu, Japan
[5]Key Laboratory of Behavioral Science, Institute of Psychology, Chinese Academy of Sciences, Beijing, PR China

English words with an inconsistent grapheme-to-phoneme conversion or with more than one pronunciation ("homographic heterophones"; e.g., "lead"–/lɛd/, /lid/) are read aloud more slowly than matched controls, presumably due to competition processes. In Japanese kanji, the majority of the characters have multiple readings for the same orthographic unit: the native Japanese reading (KUN) and the derived Chinese reading (ON). This leads to the question of whether reading these characters also shows processing costs. Studies examining this issue have provided mixed evidence. The current study addressed the question of whether processing of these kanji characters leads to the simultaneous activation of their KUN and ON reading, This was measured in a direct way in a masked priming paradigm. In addition, we assessed whether the relative frequencies of the KUN and ON pronunciations ("dominance ratio", measured in compound words) affect the amount of priming. The results of two experiments showed that: (a) a single kanji, presented as a masked prime, facilitates the reading of the (katakana transcriptions of) their KUN and ON pronunciations; however, (b) this was most consistently found when the dominance ratio was around 50% (no strong dominance towards either pronunciation) and when the dominance was towards the ON reading (high-ON group). When the dominance was towards the KUN reading (high-KUN group), no significant priming for the ON reading was observed. Implications for models of kanji processing are discussed.

Keywords: Reading aloud; Masked priming; Japanese kanji; Pronunciation; Phonology; Homographic heterophony.

Correspondence should be addressed to Rinus Gerardus Verdonschot, School of Languages and Cultures, Nagoya University, Furo-cho, Chikusa-ku, Nagoya-shi, Aichi-ken, 464-8601, Japan. E-mail: rinusverdonschot@gmail.com

R.V.'s research is presently supported by a Japanese Society for the Promotion of Science (JSPS) postdoctoral fellowship for foreign researchers (P12315). The authors would like to thank Clemens Poppe for his support with the stimuli of Experiment 1 and John Phillips, Nanae Murata, Chikako Ara, Satoru Muraoka, Yayoi Miyaoka, and Ritsuko Kikusawa for their help in recruiting and testing participants in Japan. Also we would like to thank Jennifer Burt and two anonymous reviewers for their valuable suggestions on this manuscript.

Reading aloud words is a task that is carried out seemingly easily and rapidly. However, the underlying process mechanisms are complex and need to deal with various forms of ambiguity, including the processing of heterophonic homographs (identically written words having more than one pronunciation, e.g., "dove" in "a *dove* [dʌv] is a bird" and "he *dove* [dəʊv] into the sea"). In Indo-European languages such as English it has been shown that these words are named slower than their matched controls (even when context was provided), which might be due to competition between the simultaneously activated alternative pronunciations (Folk & Morris, 1995; Gottlob, Goldinger, Stone, & Van Orden, 1999; Kawamoto & Zemblidge, 1992; Seidenberg, Waters, Barnes, & Tanenhaus, 1984). Another example of ambiguity can be found in exception words (i.e., words that do not consistently follow orthography-to-phonology conversion, OPC, rules, e.g., STEAK). These words are named more slowly than words that obey OPC rules like BEAK and PEAK, most likely due to a conflict between the stored knowledge of the word's pronunciation and OPC regularities for similar orthographic patterns (Glushko, 1979; Stanovich & Bauer, 1978; see also Seidenberg et al., 1984). Waters and Seidenberg (1985) replicated these findings, but only found the consistency effect for low-frequency words. However, Jared (1997) reported consistency effects for high-frequency words as well.

In an influential paper, Wydell, Butterworth, and Patterson (1995) extended these investigations to Japanese kanji, which have distinctly different properties to those of alphabetic scripts. Modern Japanese uses three scripts: moraic hiragana and katakana (together called kana) and logographic kanji. Lexical morphemes, such as nouns and the roots of verbs and adjectives, are usually written in kanji, whereas grammatical morphemes (e.g., inflections and function words) are written in hiragana, and alphabetic loanwords are usually written in katakana. Kanji pronunciations are divided into two types: ON readings, derived from the Chinese pronunciation, and KUN readings native to Japanese. Importantly, approximately 60% of the 1,945 commonly used kanji (Tamaoka, Kirsner, Yanase, Miyaoka, & Kawakami, 2002) are heterophonic homographs (i.e., they have both ON and KUN readings) for which the pronunciations depend on the intraword or sentence context. According to Tamaoka et al., (2002), kanji that have only ON or only KUN readings, regardless of the number of pronunciations, total 779 (739 for ON reading and 40 for KUN reading), or about 40% of the basic kanji.

Usually, there is a tendency that when a kanji character stands alone, the KUN pronunciation is used (e.g., 水 /mizu_{kun}/ "water"; subscript denoting the type), and when a kanji is part of a compound, the ON reading is used. However, there are many exceptions to this rule (e.g., the kanji "水" in 海水, /kai_{on}-sui_{on}/ "seawater", and 雨水, /ama_{kun}-mizu_{kun}/ "rainwater"). For some kanji, the meaning changes when the pronunciation changes but there are also many kanji for which this is not the case (as many Sino-Japanese and original Japanese pronunciations essentially carry the same meaning).

Wydell et al. (1995) defined consistency in terms of print-to-sound correspondences (i.e., having one or more ON and/or KUN readings). For instance, words including the character 水 were termed "inconsistent" as the pronunciation of 水 varies across its orthographic neighbourhood. Consistent words were words for which there would be, for example, just one pronunciation for each character (e.g., 駅員 /eki_{on}-in_{on}/ "station attendant"). Wydell et al. (1995) did not find any consistency effects in word-naming latencies across five experiments using two-kanji words and one experiment using single-kanji words. Hence they concluded that the computation of phonology from a written kanji is mainly computed at the whole word (i.e., compound) level and not at the level of its subcomponents (i.e., individual kanji). However, using a somewhat different approach, other researchers such as Fushimi, Ijuin, Patterson, and Tatsumi (1999) did find significant consistency effects. Particularly, when *typicality* was introduced as a factor (i.e., how often a kanji appears with a specific pronunciation at a specific position in a compound), significant consistency effects were found when Japanese compound words and nonwords were named. This led to the contrasting interpretation that pronunciation processing can be affected by character–sound correspondences at the subcomponent level (individual kanji) and not only at the whole-word level.

However, it is important to appreciate that a major difference between previous consistency experiments in English (e.g., Glushko, 1979; Jared, McRae, & Seidenberg, 1990) and Japanese (Fushimi et al., 1999; Wydell et al., 1995) pertains to the fact that English stimuli examined were usually single words, and Japanese stimuli were mostly compounds. As Wydell et al. (1995, p. 1157) put it: "comparing 'HASTE vs. CASTE' in English would in Japanese be similar to comparing compounds such as 'BOW-TIE' vs. 'BOW-WOW' or 'LEAD-IN' vs. 'LEAD-FREE'". This may be an essential difference as there is still an ongoing debate regarding whether compound words are stored in a decomposed way—that is, stored in terms of their constituent morphemes at the lexical–phonological or lexeme level (Levelt, Roelofs, & Meyer, 1999) or in their full form (Caramazza, 1997). For instance, Bien, Levelt, and Baayen (2005), using a speech preparation task, found that Dutch participants are sensitive to a compound's constituent morpheme frequency, indicating *decomposed* storage. However, another study by Janssen, Bi, and Caramazza (2008) used picture naming in Chinese and English to verify whether manipulating the frequency of a compound's constituents influences reaction times. In both Chinese and English, they found no evidence of storage in terms of their constituents, supporting the full-form storage account (e.g., Caramazza, 1997).

Additionally, there are scholars who have suggested a single-route approach including a number of processing stages (obligatory decomposition, e.g., Taft, 2004). Others have suggested dual-route models, which assume parallel (and/or interactive) processing of the full form of a compound word and its constituents (e.g., Baayen & Schreuder, 1999; Kuperman, Schreuder, Bertram, & Baayen, 2009). The latter authors, for instance, used eye tracking to establish the time course of processing Dutch polymorphemic compound words. They found early compound frequency effects, indicating that not all constituents needed to be accessed before the word-identifying process started, but also found interactions between (a) the compound frequency versus left-constituent frequency and (b) the number of combinations the left constituent could make with the right constituent versus the frequency of the right constituents. These findings indicate that both compound (i.e., full-form) information and constituent (i.e., decompositional) information influence each other and may therefore not be independent (Kuperman et al., 2009). Although the debate is clearly not settled yet, it should be noted that the relative importance of representations at particular levels may depend on the morphological complexity of a language (e.g., Chinese being a syllabic language).

As indicated earlier, there is presently mixed evidence regarding whether or not consistency as a factor independently exerts an effect on naming latencies when reading aloud Japanese kanji words or whether effects only can be obtained when other factors such as "typicality" are introduced. Additionally, as multiple pronunciations are the rule rather than the exception in Japanese, it may be that although multiple pronunciations are activated, Japanese speakers may simply address such conditions more efficiently and hence not show any processing differences between kanji characters with one or multiple readings. This is in line with data from Wydell et al. (1995). For instance, in their Experiment 5, these authors used single kanji, which were usually read using their KUN reading. These kanji could have either a single alternative (ON) reading or two alternative (ON) readings. Naming latencies did not differ between these two kanji categories, indicating that either no activation had spread to the alternative reading, or that alternative readings had little impact. In their study, however, it was not clear what the KUN/ON dominance ratios were—that is, whether the alternative readings for their stimuli were frequent or rare (see Nomura, 1978; Tamaoka & Makioka, 2004). This information may be important, as Kayamoto, Yamada, and Takashima (1998) reported mixed results for single kanji naming, which crucially depended on the relative frequencies of the alternative readings. In their first experiment, participants were asked to name kanji that had only one reading—that is, 駅 /eki$_{on}$/ "station"—versus kanji that had multiple readings—that is, 雄 /osu$_{kun}$/ (free-morpheme) or /yuu$_{on}$/ (bound-morpheme) both of which mean "male". Kayamoto et al. used high-frequency and midfrequency kanji and found in both cases a large increase in naming latency for kanji with multiple readings compared to kanji with single readings (63 ms and 88 ms, respectively) even though most alternative readings were not free morphemes. Additionally, in some cases, when naming rapidly, participants even mistakenly pronounced a blend of both readings, such as /oyuu/ for 雄, mixing up KUN reading of /osu/ and ON reading of /yuu/.

Importantly, in the first experiment of Kayamoto et al. (1998), the alternative readings (ON) had a high frequency of occurrence, which may have caused the observed difference in naming latency between the multiple-reading and single-reading kanji. To investigate this issue, in Experiment 2 the authors examined kanji with a subordinate (weaker) alternative reading and hence a stronger dominant reading. Using these stimuli, the competition effect disappeared—that is, reading kanji with multiple readings only took (a statistically nonsignificant) 10 ms more than reading single pronunciation kanji. Kayamoto et al. (1998) concluded that competition between readings created the processing cost in their first experiment, and the absence of competition in their second experiment was due to insufficient strength of the rival reading to be a competitor to the dominant reading.

It is important to realize that Kayamoto et al. (1998) and Fushimi et al. (1999) needed to make a critical assumption regarding consistency effects —namely, that *more than one pronunciation was activated at some point* in processing the word. However, this is not directly established by their data. The current study therefore aims to obtain direct evidence on whether or not multiple readings of a single kanji character become active. Studying this phenomenon using Japanese scripts provides an excellent opportunity, as most kanji essentially have more than one pronunciation, which makes stimulus selection easy (opposed to English or Dutch). Also, importantly, prime pronunciations can be transcribed in one of the kana scripts (i.e., hiragana or katakana) without invoking any orthographic overlap. Additionally, we aim to investigate whether the strength of the alternative reading plays a role. For example, is activation of more than one pronunciation detectable even when alternative pronunciations are weak (have a low frequency).

We report the results of two masked priming experiments using kanji primes and their KUN and ON transcriptions in katakana. The first experiment employs kanji with two readings, which have an equal dominance ratio (DR; in compounds; taken from the 2004 database by Tamaoka and Makioka downloadable from http://www.lang.nagoya-u.ac.jp/~ktamaoka/). This experiment is similar to Kayamoto et al.'s (1998) first experiment, as dominant and alternative readings were comparable in frequency of occurrence. In the first experiment, we also manipulated masking duration—that is, we included trials with and without a backward mask (consisting of three hash marks, ###, lasting for 50 ms). This was done in case activation spreading for one of the pronunciations would take longer to build up. In this way, we could investigate whether prolonging activation spreading (without extending the actual prime exposure duration) might allow alternative pronunciations to emerge in case they would not in trials without a backward mask. The second experiment employs kanji, which are biased to one of the pronunciations. That is, the dominant reading is much more frequent than the alternative reading. In that sense, it is comparable to the second experiment of Kayamoto et al. (1998).

Our hypotheses are straightforward: If native Japanese speakers activate multiple pronunciations when processing a kanji prime with alternative readings, then the naming of the *transcriptions* of both readings in katakana when preceded by the same congruent kanji prime should show facilitation compared to control primes (e.g., both ミズ andスイ should benefit from the 水prime compared to an unrelated prime). If the activation of nondominant readings is limited or absent, we expect the priming effect for the nondominant katakana transcription (スイ for 水) to be smaller or absent compared to the effect for the dominant katakana transcription (ミズ for 水). Such a result would assist in accounting for the absence of processing costs in earlier studies such as Wydell et al. (1995) and Kayamoto et al. (1998; Experiment 2). Furthermore, as the task involves the speech production apparatus (i.e., reading aloud katakana strings), it will also provide insights into the production processes involved when speakers are faced with potentially competitive pronunciations.

EXPERIMENT 1: READING ALOUD KATAKANA TARGETS PRECEDED BY KANJI PRIMES WITH EQUAL READING PREFERENCE

We employed a katakana word-naming task preceded by masked kanji primes. Masked priming is assumed to prevent possible strategic influences, which may hinder or bias the results (Forster & Davis, 1984). This first experiment was performed using kanji, which, in compounds, have an approximately equal (or balanced) dominance ratio for one or the other pronunciation. If there is indeed concurrent activation of multiple readings, then kanji having approximately balanced readings are likely candidates to detect this.

Method

Participants

Forty undergraduate students from Hiroshima University (23 female, 17 male; average age 20.5 years; $SD = 1.8$) 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

Twenty-nine kanji primes with two possible pronunciations were selected, which adhered to an equal KUN/ON dominance ratio (henceforth called DR) of between 40% and 60% (mean summed average 50.9%)—that is, a kanji character is pronounced approximately equally often with the Sino-Japanese (ON) and the native Japanese (KUN) reading in compound words (for a detailed description of how this statistic is obtained see Tamaoka et al., 2002, p. 272). Although there is a strong bias towards the KUN reading for standalone kanji, if activation does spread unhindered to more than one pronunciation upon seeing a kanji, there will be a good chance of obtaining significant priming for the alternative (ON) pronunciation as well (in kanji having DRs between 40 and 60%). Target strings were katakana transcriptions of the KUN and ON reading for a kanji character—for instance, 町 (city or block) was transcribed as マチ /$mati_{kun}$/ (KUN target) and チョウ /$tyoo_{on}$/ (ON target). We chose to transcribe words into katakana instead of hiragana to avoid tapping into lexical processes, as transcriptions into katakana are less familiar to participants than are those into hiragana. Additionally, Hino, Lupker, Ogawa, and Sears (2003) showed that masked repetition priming effects between kanji and katakana can be obtained reliably. Twenty-nine kanji control primes were selected, which had one (i.e., ON) preferred reading and were phonologically and semantically unrelated to the targets. The summed kanji frequencies (Yokoyama, Sasahara, Nozaki, & Long, 1998) of repetition and control primes were equated as much as possible, with a mean summed character frequency of 631.4 for repetition primes and 598.4 for control primes, $t(28) < 1$, *ns*, as were the summed stroke complexities, with a mean of 9.8 for repetition primes and 10.6 for control primes, $t(28) < 1$. All kanji were taken from the set of 1,945 commonly used Japanese kanji as published by the Japanese government in 1981 (for detailed information, see Tamaoka & Makioka, 2004; Yasunaga, 1981). Also we included a "neutral" condition, in which targets were not preceded by any prime but simply by percentage signs, to verify whether the KUN or ON targets already showed a naming latency difference without the influence of a prime. See Appendix A for an overview of the materials used in this experiment.

Design

A 2 (backward mask: present or absent) × 2 (target type, i.e., KUN and ON katakana target) × 3 (prime type, i.e., congruent, control, or neutral) within-participants factorial design was implemented. Each participant saw 348 trials (2 × 2 × 3 × 29). Four pseudorandom lists were constructed such that phonologically or semantically related primes or targets had at least a distance of two trials to avoid unintended priming effects. Within participants, the order of lists was counterbalanced. Half of the participants for a particular list saw the backward masking condition first, and the other half saw the condition without backward masking first.

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-inch LCD computer screen (Eizo Flexscan P1700 with a screen cycle refresh rate of 60 Hz) in a quiet room at Hiroshima University and were tested individually. A trial comprised the presentation of a fixation cross (1,000 ms) followed by a forward mask—identical to the backward mask—for 500 ms, and subsequently a kanji prime (50 ms), replaced either immediately by the katakana target word (maximally three characters long), which disappeared when the participant responded or after maximally 2,000 ms, or by the backward mask (50 ms), which in turn was replaced by the katakana target word. In between trials, a random interstimulus interval of 400–800 ms was introduced to avoid expectancy effects. 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 presence of the prime. After the experiment, as in earlier studies, informal interviewing showed that participants were found to be generally unable to recognize the primes under the masking conditions used in this study (see also prime visibility tests reported by Schiller, 1998, 2004 under analogous conditions). Participants were furthermore presented with a questionnaire containing the kanji used in the experiment and were asked to write down their preferred pronunciation of the kanji in a script of their choice (hiragana, katakana, or romaji).

Results and discussion

Naming latencies exceeding 2.5 standard deviations per participant per backward mask were counted as outliers (comprising 2.5% of the data). Separate analyses were carried out with participants (F_1) and items (F_2) as random variables. In the F_2 analysis, target type was considered to be a between-item variable (necessitated by the KUN/ON transcriptions of the readings of the prime). In Table 1, mean reaction times (RTs) and error rates per condition are reported. Since there were only 0.93% errors overall, distributed approximately equally across conditions in Experiment 1, error percentages were not subjected to any statistical analysis.

Table 1. *Mean naming latencies and percentage errors for Experiment 1 as a function of target type, prime duration, and experimental condition*

Katakana target	*Prime condition*	*No-BWM RT*	*+BWM RT*	*%E*
KUN reading (e.g., マチ "machi")	Congruent (町)	465 (44)	446 (43)	0.1
	Control (式)	482 (44)	465 (46)	0.0
	Congruent–control	18 (10)	19 (12)	0.1
ON reading (e.g., チョウ "tyoo")	Congruent (町)	471 (47)	453 (46)	0.0
	Control (式)	483 (47)	460 (41)	0.1
	Congruent–control	12 (9)	7 (15)	−0.1

Note: RT = reaction time (naming latency), in ms. Standard deviations in parentheses. BWM = backward mask. %E = percentage error.

First, to rule out the possibility that there was a difference in bare naming latencies between KUN or ON targets, we analysed the part in which targets were not preceded by a prime (i.e., the "neutral" condition). On these data we performed a 2 (backward mask) × 2 (target type) analysis of variance (ANOVA) analysis and found that naming latencies did not differ whether the target was transcribed in the KUN or ON reading. Also there was no interaction between backward mask and target type (all Fs < 1). As RTs were indistinguishable when there was no prime preceding the targets (indicating that bare KUN or ON naming latencies did not differ), subsequent analyses were performed without the neutral condition.

Subsequently, we performed a 2 (backward mask: present, absent) × 2 (target type) × 2 (prime type, i.e., congruent, control) analysis. There was a main effect of backward mask. Introducing a backward mask of 50 ms resulted in response latencies 19 ms faster overall, $F_1(1, 39) = 23.37$, $MSE = 1{,}280.14$, $p < .001$; $F_2(1, 56) = 323.53$, $MSE = 88.1$, $p < .001$. There was no interaction between backward mask and any of the other variables (all Fs $<$ 1 except the F-value in the three-way interaction in the participant analysis between backward mask, target type and prime type, $F_1(1, 39) = 2.52$, $MSE = 76.3$, *ns*; $F_2 < 1$).

There was no effect of target type (KUN or ON), $F_1(1, 39) = 3.120$, $MSE = 156.01$; $F_2 < 1$. However, there was a significant effect of prime type, $F_1(1, 39) = 220.84$, $MSE = 70.7$, $p < .001$; $F_2(1, 56) = 48.1$, $MSE = 265.9$, $p < .001$, and a significant interaction between target type and prime type in the participant analysis, $F_1(1, 39) = 22.6$, $MSE = 70.0$, $p < .001$; but not the items analysis, $F_2(1, 56) = 2.41$, $MSE = 110.1$, *ns*.

Planned comparisons show that without the backward mask, KUN targets were named 18 ms faster when preceded by a related prime than when preceded by a control prime, $t_1(39) = 11.0$, $SD =$ 10.2, $p < .001$; $t_2(28) = 4.8$, $SD = 20.2$, $p < .001$, and ON targets were named 12 ms faster when preceded by a related prime than when preceded by a control prime, $t_1(39) = 8.2$, $SD = 9.2$, $p < .001$; $t_2(28) = 5.3$, $SD = 18.8$, $p < .001$. When the backward mask is introduced, KUN targets were named 19 ms faster when preceded by a related prime than when preceded by a control prime, $t_1(39) = 9.4$, $SD = 12.8$, $p < .001$; $t_2(28) = 3.4$, $SD = 19.6$, $p < .01$, and ON targets were named 7 ms faster when preceded by a related prime than when preceded by a control prime, $t_1(39) = 2.9$, $SD = 15.5$, $p < .01$; $t_2(28) = 3.0$, $SD = 18.9$, $p < .01$.

It could be argued that as kanji primes were selected such that they adhered to an approximately balanced DR, half of the participants may have preferred one specific reading and the other half the other reading, and hence we obtained priming effects for both targets. This argument, however, is not in line with the results of the item analysis nor with the results of the questionnaire. If we look at an item-by-item basis, then for KUN pronunciations such as マチ /mati_{kun}/ (primes: 町 vs. 式), only 1 out of 40 participants did not show a priming effect, and for ON pronunciations such asチョウ /tyoo_{on}/, this number was 3 out of 40. Moreover, the questionnaire demonstrated that there was strong consensus (>90%) about the stand-alone pronunciation of the kanji (i.e., almost all participants transcribed 町 as /mati_{kun}/ and not as /tyoo_{on}/), indicating that the priming effect for /tyoo_{on}/ is not due to the fact that this was the preferred stand-alone reading for half of the participants.

In this experiment we obtained clear evidence that the same kanji prime concurrently activates both its pronunciations—that is, both マチ /mati_{kun}/ and チョウ /tyoo_{on}/ show faster RTs when preceded by 町 than when preceded by an unrelated prime. There was suggestive evidence for a stronger facilitation effect for the KUN reading (however, the interaction was not significant by items). This may possibly be due to the fact that the kanji primes were presented in isolation, and isolated kanji usually take the KUN reading.

EXPERIMENT 2: READING ALOUD KATAKANA STRINGS PRECEDED BY KANJI PRIMES HAVING EQUAL AND HIGH-ON/HIGH-KUN READINGS

It is conceivable that the obtained facilitation effect observed in Experiment 1 for both ON and KUN targets is only obtained for kanji that have an equal dominance ratio (e.g., Kayamoto et al., 1998). Therefore, in Experiment 2 we examined whether or not evidence for activation of multiple pronunciations could also be obtained for kanji, which have a preference/bias towards one of the readings. Furthermore, control primes in Experiment 1 typically took only one (ON) reading (according to the Joyo kanji list, e.g., 式), which might have potentially affected the results. This was resolved in Experiment 2 in which both congruent and control primes take multiple readings.

In order to ascertain that the findings of Experiment 1 are replicable, Experiment 2 included kanji primes that have an equal DR in addition to kanji primes that have a bias towards either the ON or the KUN reading. This offers the advantage of a comparison between these three types of DR within the same group of participants. Experiment 2 sought also to resolve some methodological issues concerning Experiment 1 such as the many repetitions of stimulus materials in that experiment. As Experiment 1 did not show any interaction between backward mask and other variables, the backward mask was left out to reduce the number of repetitions. As kanji primes are selected that have a bias towards a specific reading (KUN or ON), there are two possibilities: (a) The prime spreads more activation to the dominant pronunciation than to the nondominant pronunciation, which will result in more facilitation for the dominant one, (b) the KUN reading will be always the most highly activated one as all primes are single kanji (default = KUN). However, in that case, the ON-biased condition should still show more priming for the ON reading than the KUN-biased condition does.

Method

Participants

Twenty-eight undergraduate students from Nagoya University (12 female; mean age: 19 years; $SD = 3.6$) took part in Experiment 2 in exchange for financial compensation. All participants were native speakers of Japanese and had normal or corrected-to-normal vision.

Stimuli

Three prime bias groups of kanji were created. Sixteen kanji primes with two possible pronunciations were selected, which adhered to a DR of between 40% and 60% (equal-kanji; mean sum: 53.6%; DRs can be found in Tamaoka & Makioka, 2004). Furthermore, 16 kanji primes were selected, which had a DR for the KUN reading between 70% and 90% (high-KUN kanji; mean sum: 78.0%) and also 16 kanji primes that had a DR for the ON reading between 70% and 90% (high-ON kanji; mean sum 79.8%), with a mean summed character frequency of 433.4 for repetition primes and 400.7 for control primes, $F(4, 90) = 1.1$, *ns*, and summed mean stroke complexity (9.7 for repetition vs. 10.2 for control primes), $F(4, 90) = 1.4$, *ns*. Generally, the average frequency of occurrence of the ON-transcribed katakana target words was higher than that of the KUN-target words, which is due to kanji homophony being much higher for ON than for KUN readings (e.g., the string /shin_{on}/ occurs more frequently than the string /mori_{kun}/ in Japanese; Tamaoka, 2005). However, the mean summed homophone count was statistically not different between the ON-target items in the equal group (13.2), high-ON group (11.8), and high-KUN group (17.6), $F(2, 45) = 1.2$, *ns*. Appendix B provides an overview of all stimuli used in Experiment 2.

Design

A 3 (prime bias, i.e., equal, high-ON, and high-KUN) × 2 (target type, i.e., KUN or ON katakana target) × 2 (prime type, i.e., congruent and control) within-participants factorial design was implemented. Each participant received half of the experimental trials (equalling 96 trials) showing each target (KUN and ON) only once to avoid repetition (all conditions appeared equally often). For each participant individually, a pseudorandomized list was created such that phonologically (e.g., 皮 /kawa/ and 髪 /kami/) or semantically related primes (e.g., 魚 "fish" and 鳥 "bird") and phonologically related targets (e.g., カベ /kabe/ and カワ /kawa/) had at least a distance of two trials to avoid unintended priming effects. Across participants, the design was complete.

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-inch LCD computer screen (Eizo Flexscan P1700; 60 Hz) in a quiet room at Nagoya University and were tested individually. A trial comprised the presentation of a fixation cross for 1,000 ms, followed by a forward mask for 500 ms, and subsequently a kanji prime of 50 ms, replaced immediately by the katakana target word (maximally three characters long), which disappeared when the participant responded or after maximally 2,000 ms. In between trials, a random interstimulus interval of 400–800 ms was introduced to avoid expectancy effects. 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 presence of the prime. After the experiment, informal interviewing showed that participants were unable to recognize the primes under the masking conditions used in this experiment.

Results

Naming latencies exceeding 2.5 standard deviations per participant per backward mask were counted as outliers (comprising 1.2% of the data). Error rates in Experiment 2 were low (0.8%) and again were distributed approximately equally across conditions; therefore they were not analysed. In the F_2 analysis, prime bias and target type were considered to be between-item variables. In Table 2, mean RTs and error rates per condition are reported.

Mean RTs were submitted to a 3 (prime bias: equal, high-KUN, high-ON) × 2 (target type: KUN or ON) × 2 (prime type: congruent vs. control) repeated measures ANOVA. There was a main effect of prime type, $F_1(1, 27) = 35.7$, $MSE = 499.9$, $p < .001$; $F_2(1, 90) = 40.5$, $MSE = 236.3$, $p < .001$, reflecting the fact that congruent primes induced a 14-ms facilitation effect compared to the control primes, and there was a main effect of prime bias, $F_1(2, 54) = 10.2$, $MSE = 270.6$, $p < .001$; $F_2(2, 90) = 4.1$, $MSE = 419.9$, $p < .05$, reflecting the fact that targets preceded by high-ON primes were named about 9 ms slower than those in the other two prime bias conditions.

There was a significant interaction between prime bias and prime type in the participant

Table 2. *Mean naming latencies and percentage errors for Experiment 2 as a function of prime bias, target type, and prime type*

		Target type			
		KUN		*ON*	
Prime bias	*Prime type*	*RT (SD)*	*%E*	*RT (SD)*	*%E*
Equal DR (マチ/チョウ)	Congruent (e.g., 町)	449 (59)	0.0	450 (62)	0.0
	Control (e.g., 沢)	468 (73)	0.1	464 (63)	0.0
	Congruent–control	−19 (28)	−0.1	−14 (23)	0.0
KUN biased DR (モリ/シン)	Congruent (e.g., 森)	453 (62)	0.0	456 (60)	0.0
	Control (e.g., 鉄)	466 (62)	0.1	460 (62)	0.2
	Congruent–control	−13 (26)	−0.1	−4 (26)	−0.2
ON biased DR (ツミ/ザイ)	Congruent (e.g., 罪)	456 (54)	0.1	460 (58)	0.1
	Control (e.g., 則)	479 (65)	0.0	472 (62)	0.1
	Congruent–control	−23 (22)	−0.1	−12 (22)	0.0

Note: DR = dominance ratio. RT = reaction time (naming latency), in ms. Standard deviations in parentheses. %E = percentage error.

analysis, $F_1(2, 54) = 3.8$, $MSE = 188.5$, $p < .05$, but not in the item analysis, $F_2(2, 90) = 1.4$, $MSE = 236.3$, *ns*, indicating that the priming effects were numerically less in the high-KUN prime condition (9 ms) than in the equal (17 ms) and high-ON (18 ms) prime-bias conditions (although this effect was not consistent over items). There was a marginal interaction between Target Type × Prime Type, $F_1(1, 27) = 4.1$, $MSE = 341.3$, $p = .052$; $F_2(1, 90) = 3.1$, $MSE = 236.3$, $p = .078$, suggesting that KUN targets may obtain more priming than ON targets when kanji primes are shown in isolation. All other interactions, including the three-way interaction between prime bias, target type, and prime type, did not reach significance, all Fs < 1.

Planned comparisons showed that in the equal group, both the KUN targets (19 ms), $t_1(27) = 3.6$, $SD = 27.8$, $p < .001$, $t_2(15) = 3.4$, $SD = 22.0$, $p < .01$, and the ON targets (14 ms), $t_1(27) = 3.3$, $SD = 23.5$, $t_2(15) = 2.3$, $SD = 24.2$, $p < .05$, showed significant priming from related compared to unrelated primes. For the high-ON group the same pattern was found—that is, KUN (23 ms), $t_1(27) = 5.7$, $SD = 22.2$, $p < .001$; $t_2(15) = 4.7$, $SD = 18.7$, $p < .001$, and ON targets (12 ms), $t_1(27) = 2.9$, $SD = 22.2$, $p < .01$; $t_2(15) = 2.5$, $SD = 20.3$, $p < .05$, both gave rise to significant priming. However, this pattern could not be convincingly found for the high-KUN group, with significant priming in the KUN targets (13 ms) subjects, $t_1(27) = 2.7$, $SD = 26.4$, $p < .05$, and marginally in the items analysis, $t_2(15) = 2.0$, $SD = 27.3$, $p = .06$, and priming was absent for the ON targets (4 ms), $t_1(27) < 1$, $t_2(15) = 1.0$, $SD = 16.0$, *ns*.

In the equal prime bias group we replicated the main finding of Experiment 1 that congruent primes facilitated the naming of both target types (KUN and ON). For example, マチ /$mati_{kun}$/ and チョウ /$tyoo_{on}$/ again showed significant facilitation when preceded by a congruent prime (町) in comparison to a control prime. Although the lack of a Prime Bias × Prime Type × Target Type and of a Prime Bias × Target Type interaction indicates that both KUN and ON readings were facilitated by a congruent prime compared to control prime irrespective of the prime bias condition, subsequent planned comparisons did show that the ON targets in the high-KUN prime bias condition were not significantly facilitated.

Although there is no conclusive statistical support for greater priming for KUN targets than for ON targets, the numerical difference and planned comparisons do seem to point in this direction. This finding would theoretically make sense as single kanji characters usually take the KUN reading, and therefore an overall bias towards the KUN reading, even in the high-ON DR group, and hence more priming of the KUN reading, may be expected. However, it seems warranted to find corroborating evidence for the presence of a Target Type × Prime Type interaction in future research.

The primary source of the interactive trend for prime bias and prime type was the weaker priming in the high-KUN prime bias condition. Although it is difficult to assess the nature of this pattern, a possible and parsimonious account is that (a) ON targets did not show significant priming, and (b) as primes were standing alone (hence favouring the KUN reading), the priming of the KUN reading may have quickly reached its maximum and is for that reason not larger than in the other two prime bias conditions, whereas its bias towards KUN did cause less spreading of activation towards its ON reading. However, the important finding is, again, that despite of this KUN bias in reading isolated kanji, ON readings for the equal and ON-biased groups were significantly facilitated, a pattern that would not be observed if only one pronunciation received activation.

GENERAL DISCUSSION

There is currently mixed evidence for the idea that reading Japanese kanji takes more time when the characters have multiple pronunciations than when they only have one pronunciation (Fushimi et al., 1999; Kayamoto et al., 1998; Wydell et al., 1995). In this study, we examined the underlying mechanism of kanji processing in more detail by determining whether in the processing of heterophonic kanji both pronunciations become activated (primed). In addition, we examined whether the size of a potential priming effect may be affected by the dominance ratio, the relative frequency of the KUN and ON readings (in compound words). To this end we employed two masked priming experiments using katakana transcriptions as targets for each of the pronunciations of the congruent kanji primes. We hypothesized that if multiple readings for kanji are activated in parallel, it should be possible to use these primes to facilitate multiple targets (by comparing congruent to control primes for each target). Additionally we hypothesized that if the alternative readings are not dominant, priming may be less or even absent. The results of the two experiments clearly show parallel activation of two pronunciations.

However, as we used single kanji primes in our experiments the ON/KUN dominance ratio in compound words may perhaps not have been the best predictor of the relative activation spreading to the two pronunciations. Furthermore, there is the possibility that the activation of phonological representations of kanji characters is sensitive to positional information. That is, the strength of phonological activation when a character is presented in isolation may be different from the strength of phonological activation when the same character is presented as the first or second constituent of a compound.[1] Therefore, it is necessary in future experiments to establish whether a similar pattern of results is found when the kanji characters used as primes form part of a compound. This has the additional advantage that for compound words, the frequency of occurrence of the constituents is directly available in the literature.

Despite these considerations, we believe that the unique nature of Japanese kanji having multiple readings can be used to inform the debate about how compounds are processed (i.e., full-form, decomposed, or dual-route). Our results show that in Japanese kanji more than one pronunciation receives activation, as we found that ON readings (which are typically bound morphemes in our stimuli) also show significant priming (i.e., across Experiment 1, and the equal DR and high-ON group in Experiment 2) even when primes were presented in isolation. As these pronunciations would have unlikely to have been the accurate pronunciations for the stand-alone prime when shown directly (e.g., Japanese will probably not say /sui_{on}/ to 水), this does suggest that all constituents receive activation (although experiments using compound stimuli should be undertaken to assess the nature of phonological activation when a character stands alone or forms part of a compound).

Relevant information regarding this matter is provided by Tamaoka and Hatsuzuka (1995) who manipulated the frequency of individual kanji while controlling for overall compound frequency. In their experiments, compound words were presented in four conditions: (a) Left and right kanji were both high frequency—for example, 運送 /un_{on}.soo_{on}/ "transport"; (b) left was low, and right was high frequency—for example, 儀式 /gi_{on}.$siki_{on}$/ "ceremony"; (c) left was high, and right was low—for example, 軍曹 /gun_{on}.soo_{on}/; or (d) both were low frequency—for example, 我慢 /ga_{on}.man_{on}/. They found that reading aloud compound words with a high first-constituent frequency was faster (30 ms) than for those with a low first-constituent frequency, while this effect was absent for the second constituent in reading aloud (but present in a lexical decision task). However, Tamaoka and Hatsuzuka did not control for DR and total number of readings for each constituent, which the current findings indicate to be a potentially important other factor.

Our findings consistently showed that kanji characters activate multiple phonological representations. The competition that might be the result of this may be responsible for the increased word-naming latencies for heterophonic homographs, observed in some studies (Folk & Morris, 1995; Gottlob et al., 1999; Kawamoto & Zemblidge, 1992; Seidenberg et al., 1984). It is important to note that the priming effects we reported surfaced in experiments in which there was no direct task on the kanji (as they were masked primes). Instead, in our task the activation spreading from

[1] We thank an anonymous reviewer for pointing this out to us.

a kanji prime to the target reading (KUN or ON) only adds to the large amount of activation that this target reading (KUN or ON) receives from the visually presented katakana target. Given these conditions, the activation of the competing reading (the reading that does not correspond to the katakana target) is most likely insufficient to influence the selection of the correct reading. This situation differs from the situation in the Kayamoto et al. (1998) and Fushimi et al. (1999) studies in which participants were asked to name the kanji words directly. In this situation, the two readings of the target only receive activation from the target, which makes it more probable that the activation of the incorrect, competing reading delays the selection of the correct one. Recent studies from our lab showed that when kanji characters needed to be named, superimposed, semantically (Verdonschot, La Heij, & Schiller, 2010) and phonologically (Verdonschot, La Heij, Paolieri, Zhang, & Schiller, 2011) related context pictures facilitated naming in comparison to unrelated pictures. In line with the conclusion from Kayamoto et al. (1998), we proposed a selection cost for multiple reading kanji (in contrast to English, Dutch, and Chinese), especially when the DR was equal (50%) thereby allowing context pictures to exert an effect. In future experiments, it would be useful to have ON reading katakana primes paired with single kanji targets to be named in their KUN reading. For example, 水 can be pronounced as /$mizu_{kun}$/ or /sui_{on}/ but when it stands alone it will always be pronounced as /$mizu_{kun}$/. Therefore, if one uses水as the *target*, the ON reading prime such asスイ /sui_{on}/ may make it more difficult to name that kanji in its KUN reading—that is, /$mizu_{kun}$/—than would an unrelated prime. If this pattern is found, it provides evidence regarding a competitive nature of phonological selection in naming Japanese kanji.

As mentioned above, our current findings can be further extended by examining the processing of compound kanji where ON reading priming can be studied without a stand-alone KUN influence. Additionally, parametric mapping of kanji characters that have many pronunciations such as 上 /ue_{kun}/ (which can be pronounced in six different ways) will lead to a more detailed understanding of how pronunciations are accessed when there are not one but many alternatives and potentially how the correct pronunciation can be resolved.

Overall, we conclude that when native Japanese speakers encounter kanji characters, multiple readings receive activation, particularly when kanji primes have an equal DR. These pronunciations can induce priming, as in our present study, or interference (Kayamoto et al., 1998) depending on the relative strengths of alternative readings and the task at hand.

Original manuscript received 14 August 2012
Accepted revision received 22 January 2013
First published online 20 March 2013

REFERENCES

Baayen, R. H., & Schreuder, R. (1999). War and peace: Morphemes and full forms in a non-interactive activation parallel dual route model. *Brain and Language*, *68,* 27–32. doi:10.1006/brln.1999.2069

Bien, H., Levelt, W. J. M., & Baayen, H. (2005). Frequency effects in compound production. *Proceedings of the National Academy of Sciences*, *102,* 17876–17881. doi:10.1073/pnas.0508431102

Caramazza, A. (1997). How many levels of processing are there in lexical access? *Cognitive Neuropsychology*, *14,* 177–208. doi:10.1080/026432997381664

Folk, J. R., & Morris, R. K. (1995). The use of multiple lexical codes in reading: Evidence from eye movements, naming time, and oral reading. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *21,* 1412–1429. doi:10.1037/0278-7393.21.6.1412

Forster, K. I., & Davis, C. (1984). Repetition priming and frequency attenuation in lexical access. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *10,* 680–698. doi:10.1037/0278-7393.10.4.680

Fushimi, T., Ijuin, M., Patterson, K., & Tatsumi, I. F. (1999). Consistency, frequency, and lexicality effects in naming Japanese kanji. *Journal of Experimental Psychology: Human Perception and Performance*, *25,* 382–407. doi:10.1037/0096-1523.25.2.382

Glushko, R. J. (1979). The organization and activation of orthographic knowledge in reading aloud. *Journal of Experimental Psychology: Human Perception and Performance*, *5,* 674–691. doi:10.1037//0096-1523.5.4.674

Gottlob, L. R., Goldinger, S. D., Stone, G. O., & Van Orden, G. C. (1999). Reading homographs: Orthographic, phonologic, and semantic dynamics. *Journal of Experimental Psychology: Human Perception and Performance*, *25,* 561–574. doi:10.1037/0096-1523.25.2.561

Hino, Y., Lupker, S. J., Ogawa, T., & Sears, C. R. (2003). Masked repetition priming and word frequency effects across different types of Japanese scripts: An examination of the lexical activation account. *Journal of Memory and Language*, *48,* 33–66. doi:10.1016/S0749-596X(02)00500-4

Janssen, N., Bi, Y., & Caramazza, A. (2008). A tale of two frequencies: Determining the speed of lexical access in Mandarin Chinese and English compounds. *Language and Cognitive Processes*, *23*(7), 1191–1223. doi:10.1080/01690960802250900

Jared, D. (1997). Spelling–sound consistency affects the naming of high-frequency words. *Journal of Memory and Language*, *36,* 505–529. doi:10.1006/jmla.1997.2496

Jared, D., McRae, K., & Seidenberg, M. S. (1990). The basis of consistency effects in word naming. *Journal of Memory and Language*, *29,* 687–715. doi:10.1016/0749-596X(90)90044-Z

Kawamoto, A. H., & Zemblidge, J. (1992). Pronunciation of homographs. *Journal of Memory and Language*, *31,* 349–374. doi:10.1016/0749-596X(92)90018-S

Kayamoto, Y., Yamada, J., & Takashima, H. (1998). The consistency of multiple-pronunciation effects in reading: The case of Japanese logographs. *Journal of Psycholinguistic Research*, *27,* 619–637. doi:10.1023/A:1023227904895

Kuperman, V., Schreuder, R., Bertram, R., & Baayen, R. H. (2009). Reading of polymorphemic Dutch compounds: Towards a multiple route model of lexical processing. *Journal of Experimental Psychology: Human Perception and Performance*, *35,* 876–895. doi:10.1037/a0013484

Levelt, W. J. M., Roelofs, A., & Meyer, A. S. (1999). A theory of lexical access in speech production. *Behavioral and Brain Sciences*, *22,* 1–75. doi:10.1017/S0140525X99001776

Nomura, Y. (1978). Kanji no johoo shori: Ondoku-kundoku to imi no fuyo [The information processing of Chinese characters (kanji): Chinese reading, Japanese reading and the attachment of meaning]. *Japanese Journal of Psychology*, *49,* 190–197. doi:10.4992/jjpsy.49.190

Schiller, N. O. (1998). The effect of visually masked syllable primes on the naming latencies of words and pictures. *Journal of Memory and Language*, *39,* 484–507. doi:10.1006/jmla.1998.2577

Schiller, N. O. (2004). The onset effect in word naming. *Journal of Memory and Language*, *50,* 477–490. doi:10.1016/j.jml.2004.02.004

Seidenberg, M. S., Waters, G. D., Barnes, M. A., & Tanenhaus, M. K. (1984). When does irregular spelling or pronunciation influence word recognition? *Journal of Verbal Learning and Verbal Behavior*, *23,* 383–404. doi:10.1016/S0022-5371(84)90270-6

Stanovich, K. E., & Bauer, D. (1978). Experiments on the spelling to sound regularity effect in word recognition. *Memory & Cognition*, *6,* 410–415. doi:10.3758/BF03197473

Taft, M. (2004). Morphological decomposition and the reverse base frequency effect. *The Quarterly Journal of Experimental Psychology*, *57A,* 745–765. doi:10.1080/02724980343000477

Tamaoka, K. (2005). The effect of morphemic homophony on the processing of Japanese two-kanji compound words. *Reading and Writing*, *18,* 281–302. doi:10.1007/s11145-005-3354-0

Tamaoka, K., & Hatsuzuka, M. (1995). Kanji niji jukuo no shori ni okeru kanji shiyou hindo no eikyou [The effects of kanji printed-frequency on processing Japanese two-morpheme compound words]. *The Science of Reading*, *39,* 121–137.

Tamaoka, K., Kirsner, K., Yanase, Y., Miyaoka, Y., & Kawakami, M. (2002). A Web-accessible database of characteristics of the 1,945 basic Japanese kanji. *Behavior Research Methods, Instruments, & Computers*, *34,* 260–275. doi:10.3758/BF03195454

Tamaoka, K., & Makioka, S. (2004). New figures for a Web-accessible database of the 1,945 basic Japanese kanji, fourth edition. *Behavior Research Methods, Instruments, & Computers*, *36,* 548–558. doi:10.3758/BF03195601

Verdonschot, R. G., La Heij, W., Paolieri, D., Zhang, Q. F., & Schiller, N. O. (2011). Homophonic context effects when naming Japanese kanji: Evidence for processing costs? *Quarterly Journal of Experimental Psychology*, *64,* 1836–1849. doi:10.1080/17470218.2011.585241

Verdonschot, R. G., La Heij, W., & Schiller, N. O. (2010). Semantic context effects when naming Japanese kanji, but not Chinese hànzì. *Cognition*, *115,* 512–518. doi:10.1016/j.cognition.2010.03.005

Waters, G. S., & Seidenberg, M. S. (1985). Spelling–sound effects in reading: Time-course and decision criteria. *Memory & Cognition*, *13,* 557–572. doi:10.3758/BF03198326

Wydell, T. N., Butterworth, B. L., & Patterson, K. E. (1995). The inconsistency of consistency effects in reading: Are there consistency effects in kanji? *Journal of Experimental Psychology: Language, Memory, and Cognition*, *21,* 1155–1168. doi:10.1037/0278-7393.21.5.1155

Yasunaga, M. (1981). Jooyoo kanji-hyoo ga umareru-made [A background history of the Jooyoo kanji list]. *Gengo Seikatsu* [Language Life], *355,* 24–31.

Yokoyama, S., Sasahara, H., Nozaki, H., & Long, E. (1998). *Shinbun denshi media no kanji: Asahi shimbun no CD-ROM-ni yoru kanji hindo hyoo* [Japanese kanji in the newspaper media: Kanji frequency index from the Asahi newspaper on CD-ROM]. Tokyo: Sanseido.

APPENDIX A

Stimulus materials from Experiment 1

KUN target	*ON target*	*Congruent prime*	*Control prime*
サカナ (/sakana/)	ギョ (/gyo/)	魚	軸
タマ (/tama/)	ギョク (/gyoku/)	玉	僚
カガミ (/kagami/)	キョウ (/kyoo/)	鏡	菌
ノキ (/noki/)	ケン (/ken/)	軒	脈
ネ (/ne/)	コン (/kon/)	根	録
ヤマ (/yama/)	サン (/san/)	山	理
フダ (/huda/)	サツ (/satu/)	札	王
バ (/ba/)	ジョウ (/zyoo/)	場	議
クラ (/kura/)	ゾウ (/zoo/)	蔵	券
ミ (/mi/)	シン (/sin/)	身	銀
ムラ (/mura/)	ソン (/son/)	村	論
ムシ (/musi/)	チュウ (/tyuu/)	虫	卓
マチ (/mati/)	チョウ (/tyoo/)	町	式
トリ (/tori/)	チョウ (/tyoo/)	鳥	託
タ (/ta/)	デン (/den/)	田	百
シマ (/sima/)	トウ (/too/)	島	官
ケ (/ke/)	モウ (/moo/)	毛	到
カベ (/kabe/)	ヘキ (/heki/)	壁	郡
ワ (/wa/)	リン (/rin/)	輪	順
カワ (/kawa/)	ヒ (/hi/)	皮	誕
ハル (/haru/)	シュン (/syun/)	春	材
カミ (/kami/)	ハツ (/hatu/)	髪	晩
ハタ (/hata/)	キ (/ki/)	旗	詩
ヒル (/hiru/)	チュウ (/tyuu/)	昼	舎
ソコ (/soko/)	テイ (/tei/)	底	刊
ハラ (/hara/)	フク (/huku/)	腹	毒
サマ (/sama/)	ヨウ (/yoo/)	様	課
タケ (/take/)	ガク (/gaku/)	岳	糖
フエ (/hue/)	テキ (/teki/)	笛	冗

APPENDIX B

Stimulus materials from Experiment 2

Prime bias	*KUN target*	*ON target*	*Congruent prime*	*Control prime*
Equal	ネ /ne/	コン /kon/	根	右
	タマ /tama/	ギョク /gyoku/	玉	油
	シマ /sima/	トウ /too/	島	先
	カベ /kabe/	ヘキ /heki/	壁	晴
	ワ /wa/	リン /rin/	輪	豊
	ハタ /hata/	キ /ki/	旗	乳
	ソコ /soko/	テイ /tei/	底	患
	サマ /sama/	ヨウ /yoo/	様	評
	マチ /mati/	チョウ /tyoo/	町	沢
	フダ 'fuda'	サツ 'satsu'	札	薬
	ヤマ /yama/	サン /san/	山	小
	ミ /mi/	シン /sin/	身	優
	ムラ /mura/	ソン /son/	村	計
	クラ /kura/	ゾウ /zoo/	蔵	林
	ハル /haru/	シュン /syun/	春	鮮
	カワ /kawa/	ヒ /hi/	皮	勉
KUN biased	モリ /mori/	シン /sin/	森	鉄
	カワ /kawa/	セン /sen/	川	要
	ユメ /yume/	ム /mu/	夢	預
	ハシラ /hasira/	チュウ /tyuu/	柱	誠
	ハシ /hasi/	キョウ /kyoo/	橋	歩
	サカ /saka/	ハン /han/	坂	壊
	マド /mado/	ソウ /soo/	窓	斉
	ハナ /hana/	カ /ka/	花	音
	スジ /suzi/	キン /kin/	筋	契
	イト /ito/	シ /sin/	糸	怖
	ハナ /hana/	ビ /bi/	鼻	呉
	キリ /kiri/	ム /mu/	霧	潤
	シオ /sio/	エン /en/	塩	捨
	ユキ /yuki/	セツ /setu/	雪	範
	スミ /sumi/	ボク /boku/	墨	穏
	ウデ /ude/	ワン /wan/	腕	昼
ON biased	タケ /take/	チク /tiku/	竹	異
	ツミ /tumi/	ザイ /zai/	罪	則
	テラ /tera/	ジ /zi/	寺	削
	クルマ /kuruma/	シャ /sya/	車	西
	タビ /tabi/	リョ /ryo/	旅	婚
	ミズ /mizu/	スイ /sui/	水	投
	メシ /mesi/	ハン /han/	飯	括
	ヌノ /nuno/	フ /hu/	布	透
	アサ /asa/	マ /ma/	麻	昔
	ワケ /wake/	ヤク /yaku/	訳	絡
	ウシ /usi/	ギュウ /gyuu/	牛	童
	キミ /kimi/	クン /kun/	君	酒
	ニワ /niwa/	テイ /tei/	庭	貴
	モモ /momo/	トウ /too/	桃	囚
	タテ /tate/	ジュウ /zyuu/	縦	桜
	チ /ti/	ケツ /ketu/	血	希