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Constituent-morpheme priming: Implications from the morphology of two-kanji compound words

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Abstract: The diversity in the morphological structure of two-kanji compound words is a matter of special concern for models of the Japanese mental lexicon. This study discusses two proposals for models of the Japanese mental lexicon – Hirose's (1992, 1994, 1996) hypotheses and a Japanese lemma-unit version of the multilevel interactive-activation framework – in terms of their ability to cope with this diversity. As the proposals make different predictions concerning constituent-morpheme priming, patterns of facilitation were examined in two experiments with five word-formation principles as experimental conditions. Experiment 1, using the long stimulus onset asynchrony (SOA) of 3000 ms employed by Hirose (1992), only found significant differences between the first- and second-element conditions in one of the word-formation conditions. Experiment 2, using a short SOA of 250 ms, confirmed the pattern of priming obtained in Experiment 1. These results are more consistent with the prediction from the Japanese lemma-unit model.

Key words: two-kanji compound words, morphological structure, mental lexicon, constituent morpheme priming, multilevel interactive-activation framework.

Due to extensive lexical borrowing from Chinese and productive native word-formation processes, the Japanese language has a rich diversity in terms of the morphological structure of compound words. For example, one interesting consequence of this diversity is the coexistence of Sino-Japanese and native Japanese compound words of almost identical meaning, such as the Sino-Japanese word 登山 /tozan/ and the native Japanese word 山登り /yamanobori/, both combinations of the morphemes 登 "climb" and 山 "mountain," meaning "mountain climbing."[2] This diversity in compound-word structure is a matter of special concern for models of the Japanese mental lexicon. Given that such models must capture in some way the morphological relations between 登山 and 山登り, as well as other compound words sharing the morphemes 登 and 山, the diversity poses

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[2] While plagued by problems (Nomura, 1988), it is common to classify the Japanese lexicon according to origin, and in the case of two-kanji compound words to distinguish between native Japanese and Sino-Japanese words. Reflecting their etymology, Sino-Japanese compound words are read according to the on-readings of the constituent kanji, which are based on Chinese pronunciations borrowed in Japanese, together with the kanji, whereas native Japanese compounds are usually read according to the kun-readings, native Japanese readings applied to kanji as translation equivalents which are used when a single kanji represents a word or a verbal or adjectival stem.

important questions about how the representations of compound words might be stored and linked together, and, reflecting this arrangement, about the nature of lexical retrieval.

In this paper, these questions are addressed with respect to the lexical storage and retrieval of two-kanji compound words. Specifically, this paper considers two proposals for the Japanese mental lexicon that differ in terms of both structure and retrieval mechanisms. While the first proposal suggested by Hirose (1992, 1994, 1996) employs search mechanisms, activation mechanisms are assumed in the second proposal, which is a lemma-unit version of the multilevel interactive-activation framework for Japanese based on the recently modified version for Chinese (Taft, Liu & Zhu, 1999). The two experiments reported in this paper were conducted because these two proposals make different predictions concerning priming from the constituent morphemes of two-kanji compound words.

The representation of morphological information is a fundamental issue for all models of the mental lexicon. This is true not only because of the vast numbers of polymorphemic words that exist in all languages and the relative ease with which language users handle both existing and novel forms (Sandra, 1994), but also because the issue has important implications for processing. The representation and organization of lexical information in the mental lexicon directly determines the nature of lexical retrieval – whether search (e.g. Forster, 1976) or activation (e.g. Taft, 1991, 1994) mechanisms are assumed, as well as the extent of morphological involvement.

Both search mechanisms and activation mechanisms have been suggested for the Japanese mental lexicon. Hirose (1992, 1994, 1996), for example, has evoked search mechanisms in his hypotheses concerning the organization of two-compound words based on the results from a constituent-morpheme priming study using the lexical decision task. Although significant priming was found in both constituent conditions compared to an unrelated prime condition, as reaction times were significantly faster in the first-element prime condition than in the second-element prime condition, Hirose interpreted this result as evidence of serial (from left to right) processing of the compound words. In another experiment comparing priming from the first-element when it was the first kanji of many compound words rather than of few compound words, facilitation was greater in the few-compounds condition. Based on these results, Hirose suggested that the mental lexicon for compound words is structured so that words sharing the same first kanji are linked in clusters, with the first kanji serving as a retrieval cue, but that words sharing the same kanji as a second element are not.

A number of models involving activation mechanisms have also been proposed for the Japanese mental lexicon, such as the companion-activation model advocated by Saito (1997) and an interactive-activation model suggested by Tamaoka and Hatsuzuka (1998). However, these models also face the problems associated with representational redundancy, homographs, and varying degrees of semantic transparency that motivated Taft, Liu, et al. (1999) to make a recent modification to a Chinese version of the multilevel interactive-activation framework. Accordingly, the proposal considered in this paper is an adaptation of this revised model for Japanese.

To overcome these problems, Taft, Lui, et al. (1999) replaced the level of two-character (polymorphemic) word representations assumed in earlier versions to exist above the Chinese character or morpheme-level representations (Taft & Zhu, 1995) with lemma units – abstract modality-free units mediating the links between orthographic, phonological, and semantic units.[3] Similar to the "concept nodes" proposed by Schreuder and Baayen (1995), these lemma units emerge from the regular co-occurrence of orthographic forms with meaning. Because the same basic

[3] Although Tamaoka and Hatsuzuka (1998) incorporate what they refer to as syntactic feature representations, or lemmas, in their model, these do not actually replace compound-word level representations, but rather serve as a means of representing word-class information within the model.

structure is also appropriate for the Japanese mental lexicon, adapting this revised version for Japanese is straightforward. In this model, retrieval of a two-kanji compound word is the product of the activation passing to the lemma unit representing the compound word from the orthographic-representation units for the constituent kanji.

Because any model of the Japanese mental lexicon must in some way capture the morphological relations that exist between polymorphemic words, one may ask how well these two proposals cope with the diversity inherent in the morphological structure of two-kanji compound words. Although approximately nine main principles or relationships are generally accepted as underlying the formation of two-kanji compound words (see Nomura, 1988; also, Kageyama, 1982; Tamamura, 1985), this study will focus on the five principles that were used as experimental conditions in the two experiments reported here.[4] The first three principles, which are syntactic in nature, are modifier + modified (e.g. 山 "mountain" + 桜 "cherry" in 山桜 /yamazakura/ "mountain cherry"), verb + complement (e.g., 登 "climb" + 山 "mountain" in 登山 / "mountain climbing," and complement + verb (e.g., 外 "outside" + 食 "eat" in 外食 /gaishoku/ "eating out"). The last two principles, which are semantic in nature, are associative pairs (e.g., 男 "man" + 女 "woman" in 男女 /danjo/ "men and women") and synonymous pairs (山 "mountain" and 岳 "mountain" in 山岳 /sangaku/ "mountains") (Joyce & Ohta, 1999).

From a storage perspective, such diversity clearly poses problems for Hirose's (1992) hypothesis that compound words are linked in clusters based on the first kanji. For instance, if clusters are only based on a shared first kanji, then semantically related compounds sharing a common second kanji, such as modifier + modified compounds like 山桜 "mountain cherry" and 夜桜 "cherry blossoms at night," will not be linked. Another difficulty arises from the reversed syntactic structures of verb + complement and complement + verb. Although Hirose does not discuss native Japanese compound words like 山登り, presumably the clustering based on the first kanji extends to these compound words as well. However, this would lead to a strange situation where 登山 and 山登り would not be linked in the mental lexicon because of the reversed order of elements, even though they are almost identical in meaning. Even if native Japanese compound words are treated separately, there are still many semantically related Sino-Japanese compound words, such as 殺人 /satsujin/ "murder" ("kill" + "person") and 毒殺 /dokusatsu/ "poison" ("poison" + "kill"), that would not be linked according to Hirose's hypothesis. On the other hand, this morphological diversity is not a problem for the Japanese lemma-unit model. This is because instead of grouping morphologically related compound words in "clusters," the relations underlying morphological families are modeled by the connections between representations.

Hirose's (1992, 1994, 1996) hypotheses also appear to have problems in terms of lexical retrieval. It is slightly puzzling that Hirose's hypotheses are based on results from the constituent-morpheme priming paradigm. This is the same paradigm used by Monsell (1985) in a study involving both semantically transparent (e.g., *tightrope*) and opaque (e.g., *butterfly*) English compound words. In contrast to Hirose's pattern of facilitation, however, Monsell found similar levels of facilitation from the first and the second constituents. Although the Japanese lemma-unit model, where retrieval is based on an activation mechanism, predicts similar levels of priming from both constituent

[4] The selection of these five principles was influenced by a number of factors. While the other principles of affixation, repetition, abbreviation, and phonetic borrowing would undoubtedly also provide data of interest, they are, for varying reasons, less suitable for the present experimental design. Given the present concern with the organization of compound words in the mental lexicon, another factor was the desire to include contrasting patterns, such as the reversed syntactic patterns of verb + complement and complement + verb. In this respect, these principles break somewhat with Nomura's (1988) classification, where these syntactic patterns are relegated under a basic pattern of complements.

Table 1. Mean classification survey and familiarity survey scores for target compound words used in Experiment 1 and Experiment 2

	Experiment 1		Experiment 2	
Word formation principle	Classification survey	Familiarity survey	Classification survey	Familiarity survey
Modifier + modified	6.32 (0.29)	6.47 (0.23)	6.27 (0.25)	6.24 (0.37)
Verb + complement	6.56 (0.25)	6.24 (0.30)	6.56 (0.21)	6.02 (0.37)
Complement + verb	6.51 (0.24)	6.13 (0.27)	6.48 (0.25)	6.00 (0.30)
Associative pairs	6.85 (0.09)	6.29 (0.33)	6.83 (0.12)	6.07 (0.40)
Synonymous pairs	6.23 (0.33)	6.42 (0.22)	6.27 (0.32)	6.27 (0.32)

Both surveys used a 7-point scale: in the classification survey, 1 indicated bad examples and 7 indicated good examples; while in the familiarity survey 1 indicated low familiarity and 7 indicated high familiarity.
The figures in parenthesis are the standard deviations.

kanji, such a finding would be incompatible with the search mechanisms that Hirose has evoked given their reliance on the first kanji as a retrieval cue.

The storage of lexical information and the mechanism of lexical retrieval are mutually defining aspects of the mental lexicon. Given this and the difficulties with Hirose's (1992, 1994, 1996) hypotheses in coping with the diversity in compound-word structure, one may wonder if the pattern of facilitation found by Hirose (1992) would be observed once compound-word structure is considered. As the two proposals discussed here make different predictions concerning constituent-morpheme priming, the pattern of facilitation for two-kanji compound words is examined in two priming experiments that control for compound-word morphology by including five word-formation principles as experimental conditions.

Experiment 1

Methods

Participants. Forty-two native Japanese students (average age 20.1 years, $SD = 3.25$) of the University of Tsukuba participated in the experiment as volunteers.

Design and materials. A 3×5 two-factor design was used, with both factors as within-subject variables. The three prime conditions are first element, second element, and unrelated prime, and the five word-formation conditions are modifier + modified, verb + complement, complement + verb, associative pair, and synonymous pair.

Stimulus items were selected from a corpus of 1000 two-kanji compound words (Joyce & Ohta, 1999) that was surveyed to obtained native-Japanese evaluations for familiarity and for the appropriateness of classifying the compound words according to a particular word-formation principle. For each of the five word-formation principles, 18 compound words with evaluation scores of 5.5 or higher on a 7-point scale for both criteria were selected. The mean scores for both criteria over the five word-formation principles are shown in Table 1, as are the scores for the stimulus items used in Experiment 2.[5] Non-word combinations of two kanji were generated from this corpus by randomizing the second-element kanji, and 90 items were selected based on a survey to control for "word-like-ness."

To counterbalance the target compound words over the three prime conditions, three

[5] Subsequent to the recent publication of a lexical database (Amano & Kondo, 1999), all pertinent characteristics for these stimulus items (as well as those used in Experiment 2) were investigated. At the compound-word level, these were mora length, word orthography, and written word familiarity. At the single-character level (for both first- and second-element kanji), these were familiarity, degree known, complexity, and number of character strokes. Significant correlations ($p < 0.01$) were found between familiarity scores used in selection (Joyce & Ohta, 1999) and the database scores ($r = 0.474$ and $r = 0.5$ for Experiment 1 items and Experiment 2 items, respectively). Averaged scores for the other characteristics were all fairly closely matched.

presentation lists were prepared. Participants were assigned evenly to these lists, which were randomized for each participant. After first excluding kanji used in compound and non-word stimulus items, the kanji for the unrelated condition were randomly assigned from the most frequent 1000 Jôyô kanji (National Language Research Institute, 1976).

Apparatus. Super Laboratory Pro (Version 1.05, Cedrus Corporation, San Pedro, CA, USA), running on a personal computer (Dell, Dimension XPS D333, Round Rock, TX, USA), controlled the presentation of stimulus items and recorded lexical decisions collected via a response box (Cedrus Corporation, RB-600). Stimuli at a font size of 36 points were displayed on the computer screen at a viewing distance of approximately 50 cm.

Procedure. The procedure used for this experiment is very similar to that of Hirose's (1992) Experiment 1, with a stimulus onset asynchrony (SOA) of 3000 ms. The only difference was that participants were asked to only look at the prime, rather than to name it, which may have biased them towards the activation of phonological information. At the start of a trial, a plus symbol (+) was displayed in the center of the screen as a fixation point for 1000 ms. After this, a blank screen for 500 ms was followed by a prime kanji for 1000 ms. Following a second blank screen for 500 ms, two plus symbols (+ +) as fixation points for the target compound words were displayed for 1000 ms. After a third blank screen for 500 ms, a target compound word was displayed until the participants made a lexical decision by pressing a key on a response box. Participants were instructed to press a green button for a compound word and a red button for a non-word as quickly and as accurately as possible. The whole experiment, including a practice session of 10 trials, took between 20 min and 25 min to complete.

Results

Analyses of variance (ANOVA) were carried out for the effects of prime and word-formation principle both by subject (both factors as within-subject variables) and item (prime as a within-subject and principle as a between-subject variable). Error responses were excluded from the analysis of reaction times. Responses were also removed if the standard score for a reaction time was outside the range of ± 2.5 calculated from the mean response time for a given participant. In all, 6.4% of the 3780 responses were excluded because of these procedures. The reaction times and error rates for Experiment 1 are presented in Table 2, together with those for Experiment 2.

Error analysis. The overall error rate was low at 4.4%. Although there were significant main effects of prime in both the subject and item analyses, $F_1(2,82) = 27.00$, $p < 0.0001$; $F_2(2,170) = 30.71$, $p < 0.0001$, the main effect of word-formation principle was only significant in the subject analysis, $F_1(4,164) = 3.26$, $p < 0.013$, with no significant interaction in either analysis.

Planned comparisons using Tukey's Honestly Significant Difference (HSD) test (all significant HSD differences reported in this paper are at the 0.05 level) for the main effect of prime revealed that although errors in both the first-element and the second-element conditions were significantly lower than in the unrelated condition, the differences between the first-element and second-element conditions were not significant, HSD = 0.134 and HSD = 0.288 for the subject and item analyzes, respectively. Planned comparisons for the main effect of word-formation principle revealed that errors in the modifier + modified and the verb + complement conditions were significantly lower than in the complement + verb condition, HSD = 0.159.

Reaction times analysis. In the subject analysis, there were significant main effects for prime, $F_1(2,82) = 102.22$, $p < 0.0001$, and for word-formation principle, $F_1(4,164) = 5.34$, $p < 0.0001$, with significant interaction, $F_1(8,328) = 2.45$, $p < 0.014$. In the item analysis, there was only a significant main effect of prime, $F_2(2,170) = 56.37$, $p < 0.0001$.

Planned comparisons for the main effect of prime for each word-formation condition in

Table 2. Mean reaction times (in milliseconds) and error rates (as percentages) as a function of word formation principle and prime condition in Experiment 1 and Experiment 2

	Experiment 1			Experiment 2		
Word-formation principle	Reaction times	RT diff.	Error rate	Reaction times	RT diff.	Error rate
Modifier + Modified						
First-element	529 (70)	+54	0.4	544 (78)	+52	2.9
Second-element	544 (77)	+39	1.6	549 (72)	+47	3.3
Unrelated	583 (77)		5.6	596 (81)		6.2
Verb + Complement						
First-element	539 (81)	+55	2.0	537 (82)	+77	2.7
Second-element	558 (81)	+36	3.2	559 (79)	+55	2.0
Unrelated	594 (81)		11.5	614 (88)		5.3
Complement + Verb						
First-element	559 (78)	+48	4.0	561 (92)	+62	4.9
Second-element	551 (88)	+56	2.8	561 (76)	+62	4.0
Unrelated	607 (87)		9.1	623 (80)		8.9
Associative Pairs						
First-element	543 (86)	+54	3.2	546 (73)	+67	4.4
Second-element	539 (79)	+58	2.0	558 (91)	+55	2.9
Unrelated	597 (84)		6.7	613 (81)		7.6
Synonymous Pairs						
First-element	539 (90)	+63	4.0	528 (75)	+89	1.8
Second-element	534 (84)	+68	2.0	538 (85)	+79	0.7
Unrelated	602 (94)		8.7	617 (94)		6.0

Standard deviations are given in parentheses.

RT diff. = differences calculated from the unrelated condition reaction time in each word formation principle condition.

the subject analysis revealed that although reaction times in both the first-element and the second element-conditions were significantly faster than in the unrelated condition for all conditions, the only word-formation condition with a significant difference between first-element and second-element conditions was the verb + complement condition where the first-element was faster, $F_1(2,82) = 28.84$, $p < 0.0001$ at modifier + modified, $F_1(2,82) = 38.53$, $p < 0.0001$ at verb + complement, $F_1(2,82) = 35.21$, $p < 0.0001$ at complement + verb, $F_1(2,82) = 35.00$, $p < 0.0001$ at associative pairs, and $F_1(2,82) = 34.55$, $p < 0.0001$ at synonymous pairs, with HSD = 18.09 in all cases. Planned comparisons for the main effect of prime in the item analysis revealed that reaction times in both the first-element and the second element-conditions were significantly faster than in the unrelated condition for all conditions, HSD = 14.51.

Planned comparisons were conducted for the main effect of word-formation principle for each prime condition. In the first-element condition, reaction times were significantly faster in the modifier + modified condition compared with the complement + verb condition, $F_1(4,164) = 4.13$, $p < 0.003$, HSD = 20.33. In the second-element condition, reaction times were significantly faster in the synonymous pair condition compared with the verb + complement condition, $F_1(4,164) = 3.63$, $p < 0.007$, HSD = 20.33. In the unrelated condition, reaction times were significantly faster in the modifier + modified condition

compared with the complement + verb condition, $F_1(4,164) = 2.99$, $p < 0.021$, HSD = 20.33.

Discussion

The purpose of Experiment 1 was to examine the pattern of facilitation in constituent-morpheme priming by controlling the word-formation principle of two-kanji compound words. The results showed priming for both first- and second-element conditions. However, only the verb + complement condition matched the prediction from Hirose's (1992, 1994, 1996) hypotheses of significantly faster reaction times for the first-element. In line with the prediction from the Japanese lemma-unit model, the differences between the constituent primes were not significant in the other four word-formation conditions. The question of how the Japanese lemma-unit model could possibly account for the verb + complement pattern of priming will be taken up in the general discussion.

While the subject analyses indicated an effect of word-formation principle, no effect was indicated by the item analyses. Moreover, planned comparisons failed to show a consistent pattern in the reaction times over all three prime conditions, which one would expect if word-formation principle were indeed a variable influencing lexical retrieval.

However, one aspect of the present experiment that needs to be investigated further is the SOA of 3000 ms. Tamaoka and Hatsuzuka (1998) have criticized Hirose's (1992) experiment for its very long SOA, claiming that at such a long delay participants may adopt strategies in their lexical-decision-making. If this were so, then the results of Hirose (1992) and the present experiment might not be a true reflection of the time required for the lexical retrieval of the target stimulus items. Accordingly, Experiment 2 investigates whether the pattern of facilitation in Experiment 1 will also be found at a short SOA of 250 ms, which, based on Neely's (1977) seminal study on the distinction between automatic and expectancy-based processing, should be free from strategy-adoption.

Experiment 2

Methods

Participants. Forty-five native Japanese students (average age 19.6 yeras, $SD = 2.18$) of the University of Tsukuba participated in the experiment as volunteers. None of these participants took part in Experiment 1.

Design and materials. The design for Experiment 2 was the same as for Experiment 1.

The short SOA of 250 ms made it possible to increase statistical reliability by including more stimulus items without adding to the burden on the participants. Accordingly, the 18 compound words for each word-formation condition in Experiment 1 were supplemented with 12 additional items selected according to the same criteria from the same corpus (Joyce & Ohta, 1999). Thus, there were a total of 30 compound words for each word-formation condition in Experiment 2. The mean criteria scores for these stimulus items, which are similar to those of the Experiment 1 items, are also shown in Table 1. Three presentation lists were again prepared to counterbalance the stimulus items over the three prime conditions. Participants were assigned evenly to these lists, which were randomized for each participant.

Apparatus. This was identical to that used in Experiment 1.

Procedure. At the start of a trial, a plus symbol (+) appeared in the center of the screen as a fixation point for 250 ms. This was followed by the single kanji prime, displayed for 200 ms, and then by an asterisk-like symbol (※) as a mask for 50 ms. The target stimulus item was then displayed and remained on the screen until the participant pressed a button on the response box for the lexical decision. There was a 1500 ms intertrial interval. The whole experiment, including a practice session of 10 trials, took between 15 and 20 min to complete.

Results

Analyses of variance (ANOVA) were carried out for the effects of prime and word-formation principle both by subject (both factors as within-subject variables) and item

(prime as a within-subject and principle as a between-subject variable).[6] Following the same procedures used in Experiment 1, the data were adjusted for error responses and outliners, resulting in 5.9% of the 6750 responses being excluded.

Error analysis. The overall error rate was very low at 3.4%. Although there were significant main effects of prime in both the subject and item analyzes, $F_1(2,88) = 24.61$, $p < 0.0001$; $F_2(2,290) = 27.48$, $p < 0.0001$, the main effect of word-formation principle was only significant in the subject analysis, $F_1(4,176) = 5.79$, $p < 0.0001$, with no significant interaction in either analysis.

Planned comparisons for the main effect of prime revealed that although errors in both the first-element and the second-element conditions were significantly lower than in the unrelated condition, the differences between the first-element and second-element conditions were not significant, HSD = 0.154 and HSD = 0.216 for the subject and item analyzes, respectively. Planned comparisons for the main effect of word-formation principle revealed that errors in the synonymous pairs were significantly lower than both the complement + verb condition and associative pairs, and that errors in the modifier + modified condition were lower than for the complement + verb compounds, HSD = 0.203.

Reaction times analysis. In the subject analysis, there were significant main effects of prime, $F_1(2,88) = 162.05$, $p < 0.0001$, and of word-formation principle, $F_1(4,176) = 7.53$, $p < 0.0001$, with significant interaction, $F_1(8,352) = 2.92$, $p < 0.004$. In the item analysis, there was only a significant main effect of prime, $F_2(2,290) = 148.42$, $p < 0.0001$.

Planned comparisons for the main effect of prime for each word-formation condition in the subject analysis revealed that although reaction times in both the first-element and the second element-conditions were significantly faster than in the unrelated condition for all conditions, the only word-formation condition with a significant difference between the first-element and second-element conditions was the verb + complement condition where the first-element was faster, $F_1(2,88) = 36.18$, $p < 0.0001$ at modifier + modified, $F_1(2,88) = 66.19$, $p < 0.0001$ at verb + complement, $F_1(2,88) = 45.03$, $p < 0.0001$ at complement + verb, $F_1(2,88) = 41.79$, $p < 0.0001$ at associative pairs, and $F_1(2,88) = 79.93$, $p < 0.0001$ at synonymous pairs, with HSD = 17.50 in all cases. Planned comparisons for the main effect of prime in the item analysis revealed that reaction times in both the first-element and the second element-conditions were significantly faster than in the unrelated condition for all conditions, HSD = 10.97.

Planned comparisons were conducted for the main effect of word-formation principle for each prime condition. In the first-element condition, reaction times were significantly faster in the verb + complement and the synonymous pair compounds compared to the complement + verb condition, $F_1(4,176) = 5.46$, $p < 0.0001$, HSD = 19.32. In the second-element condition, the reaction times were significantly faster in the synonymous pair condition compared to the verb + complement, the complement + verb and the associative pair compounds, $F_1(4,176) = 3.51$, $p < 0.009$, HSD = 19.32. In the unrelated condition, reaction times were significantly faster in the modifier + modified condition compared to the complement + verb and synonymous pair compounds, $F_1(4,176) = 5.00$, $p < 0.001$, HSD = 19.32.

Discussion

The results of Experiment 2, with a short SOA of 250 ms, not only match closely the reaction times obtained in Experiment 1, with a long SOA of 3000 ms, but also provide a very similar pattern of priming, with significant differences between the first- and second-element

[6] Separate subject and item analyzes were also conducted for the 18 Experiment 1 stimulus items with the reaction time data obtained in Experiment 2. However, as the results of these were the same as the results for all 30 Experiment 2 stimulus items, only the more reliable analyzes with the larger set of stimulus items are reported here.

conditions only in the verb + complement condition. Thus, these results indicate that the reaction times in Experiment 1 were free of participant strategy-adoption, and that the basic pattern of facilitation found in both experiments is due to automatic priming from constituent morphemes.

A main effect of word-formation principle was again indicated in the subject analysis. However, again no consistent pattern was found for this in the significant differences in the planned comparisons. Moreover, the fact that the significant differences also varied across the two experiments cautions against thinking that word-formation principle per se is influencing lexical retrieval.[7] Although Tamaoka and Hatsuzuka (1998) argue that there are differences in processing times for two-kanji compound words according to morphological structure, problems concerning the appropriateness of their control group would appear to undermine the credibility of their results.[8]

General discussion

Two experiments investigated the different predictions concerning constituent-morpheme priming made by the two proposals for the Japanese mental lexicon discussed in this paper. Specifically, they sought to examine the pattern of facilitation from the constituents of two-kanji compound words once word-formation principle was controlled for as an experimental variable.

In all five word-formation conditions, the reaction times associated with both constituent conditions were significantly faster than those for the unrelated condition. However, in all but one word-formation principle, reaction time differences between the first-element and second-element conditions were not significant. That is, the present results clearly show that both related prime conditions facilitated responses to the target, and, in the majority of cases, at similar levels.

These results are clearly more consistent with the prediction from the Japanese lemma model than with the pattern of priming obtained by Hirose (1992), suggesting that a model of the Japanese mental lexicon must be capable of accounting for similar levels of facilitation from both constituents. According to the lemma model, the lexical retrieval for a two-kanji compound word is achieved by activation passing to the lemma unit representing the compound word from both the orthographic representation units for the constituent kanji characters. The priming effects found in the present experiments can be accounted for by assuming that lingering activation in lemma units linked to the orthographic unit of the prime give them an advantage over other unactivated units. When the prime is presented again as a constituent element of a compound word, this lingering activation leads to faster reaction times compared to the unrelated prime condition.

One aspect of the present results that does require further consideration is the significantly faster reaction times for the first element compared to the second element in the verb + complement condition indicated in the subject analyzes. Although Taft, Zhu, and Peng (1999) suggest that character representations are not positionally sensitive within Chinese compound words, the possible influence of word formation on positional sensitivity was not examined. However, given the central role of frequency as a regulating mechanism within the lemma-unit model, this influence cannot be ruled out. Because the lemma units function

[7] While the compound words were matched closely for familiarity, there were inevitably slight differences in the mean familiarity evaluations across the word-formation conditions, and slight shifts in these over the two experiments, as shown in Table 1. The pattern of these familiarity differences closely match the pattern of differences in reaction times across the word-formation conditions, suggesting that this was the cause of the apparent effect of word-formation principle.

[8] Tamaoka and Hatsuzuka (1998) found that opposite-concept-kanji compounds were processed more slowly than similar-concept-kanji compounds in a lexical decision task but not in a naming task, with both groups being slower than the control group in both tasks. However, inspection of their stimulus lists suggests that many of the control-group compound words are actually similar-concept-kanji compounds.

as a means of differentiating and addressing concepts, morphological relations are expressed within the model in terms of shared semantic and syntactic properties, such as restrictions on combinations, like verb and direct object, as well as information about word class and element order. Thus, the positional frequency of a kanji is likely to be closely linked to its word class and, in turn, to word formation principles at the compound level. Although this issue needs further investigation, positional sensitivity coupled with the characteristics of verb + complement compound words, which involve only Sino–Japanese elements and, as Kageyama (1982) observes, are limited to mainly verb + direct object combinations, may have been sufficient to produce the significant difference between the constituents in this word-formation principle.

Overall, the Japanese lemma-unit model provides a good account of the lexical storage and retrieval of two-kanji compound words. It is also very attractive for its potential to model the complex relationships between meaning, orthography, and phonology that arise from the Japanese writing system's multiscript nature and its dual-reading system, as shown in Figure 1. (Note that lower-level orthographic and phonological representations are not included in the figure, which focuses on the connections to lemma units).

Incorporating the lemma units to mediate the connections between semantic units and access representation units provides a simple way of explaining how both kanji and kana map on to meaning, as both 山 and やま /yama/ can be linked via a single lemma unit to the meaning "mountain." The lemma units also provide an elegant method of capturing the nuances in the use of on- and kun-readings. As already mentioned, the lemma units are connections or way-stations that develop when semantic information regularly co-occurs with form information (Schreuder & Baayen, 1995; Taft, Liu et al. 1999). The regular co-occurrence of the meaning "mountain" with the orthographic form 山 and the phonological form /yama/ will lead to the development of a lemma unit to mediate these relationships. Similarly, the co-occurrences of the meaning "mountain climbing," with both the native Japanese word 山登り /yamanobori/ and the Sino-Japanese word 登山 /tozan/ would lead to the development of two separate lemma units linking the meaning to the appropriate orthographic and phonological forms, as depicted in Figure 1.

When multiple units at the same level link to a unit at another level, it is necessary to specify the order of the links (Taft, Liu et al. 1999). Although this is indicated with numbered connections in Figure 1, the ordering of elements is actually a function of the lemma units rather than an artifact of the connections. Arguing that the central role of morphology is in computing meaning, Schreuder and Baayen (1995) posit lemma units (concept nodes) as part of a lexical representation that also includes mechanisms of licensing and composition, which operate on activated concept nodes. These mechanisms of licensing and composition appear to be related to the morphological awareness that Hatano (1995) refers to as compounding schemata – the implicit awareness of how kanji can be combined in compound words – acquired through learning to use the Japanese writing system. In his discussions, however, Hatano (1995) suggests that experienced readers of Japanese have two kinds of mental lexicons – the usual lexicon of words and a lexicon of kanji, or rather their corresponding morphemes as the building blocks for compound words. Although the notion of a separate lexicon for kanji is undoubtedly prompted by the bound nature of on-readings, the idea of two separate lexicons is far from appealing. It is also completely unnecessary, because the relationships between semantic representations for morphemes, orthographic representations for kanji, and phonological representations for both on- and kun-readings can be adequately explained through the mediation of lemma units.

Although there are issues to be considered further, the Japanese lemma unit model undoubtedly provides a extremely appealing way of thinking about the relationships that

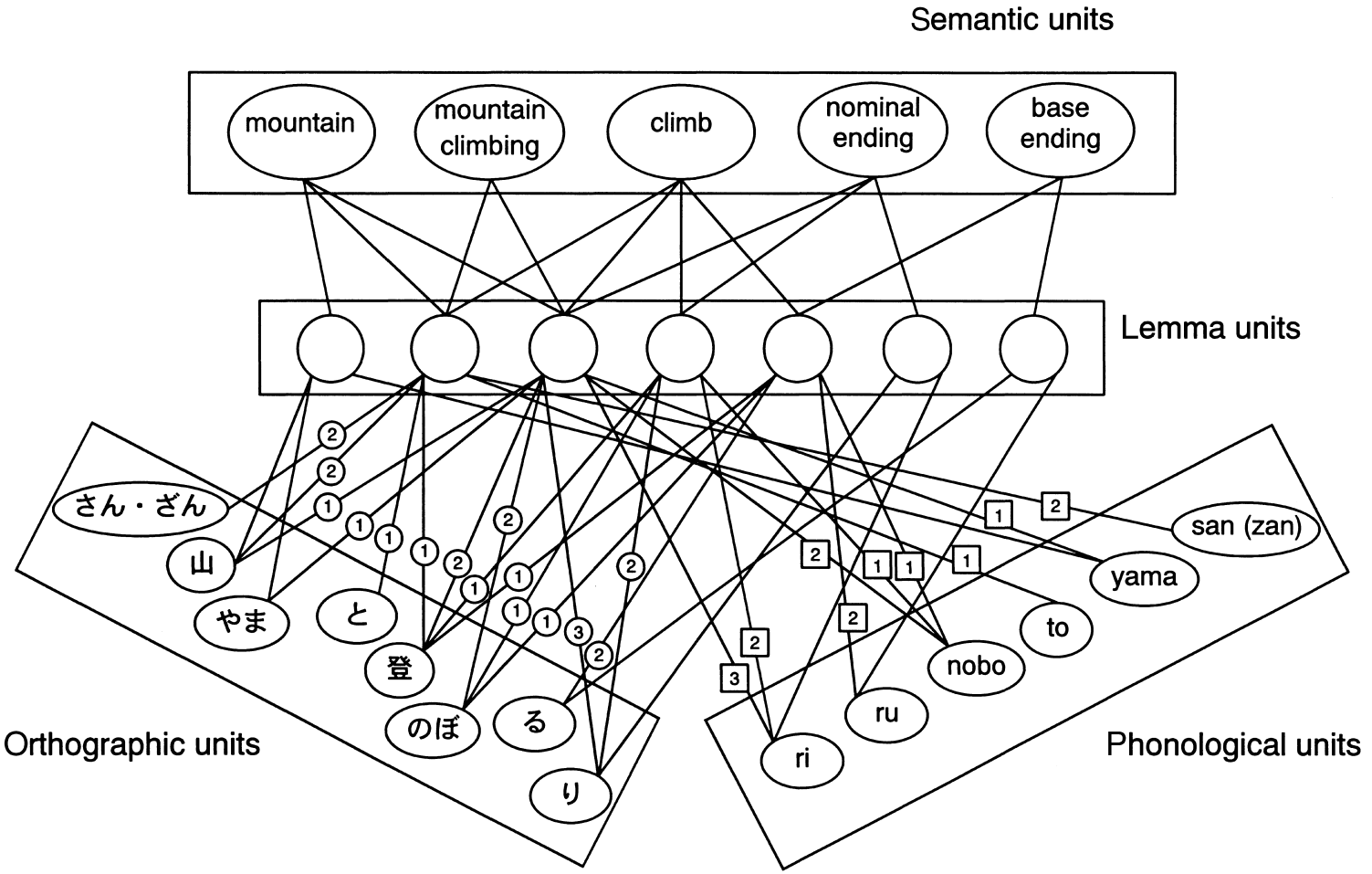

Figure 1. Lemma unit connections in a multilevel interactive-activation model for Japanese.

exist between semantic representations, and access representations for orthography and phonology, as well as the morphological information that underlies two-kanji compound words in the Japanese mental lexicon.

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