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This is a contribution from *Writing Systems, Reading Processes, and Cross-Linguistic Influences. Reflections from the Chinese, Japanese and Korean Languages*.
Edited by Hye K. Pae.

CHAPTER 11

Constituent-priming investigations of the morphological activation of Japanese compound words

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This chapter reports on two experiments conducted to investigate the morphological activation of two-kanji compound words using the constituent-morpheme priming paradigm with a series of very-brief masked stimulus onset asynchronicity (SOA) conditions. In contrast to Experiment 1 where the word-formation principle (WFP) conditions all involved Sino-Japanese (SJ) compound word targets, the WFP conditions for Experiment 2 included both SJ and native-Japanese (NJ) WFP targets. The results from both experiments provide evidence for the early contributions of morphological information to the lexical processing of compound words, in terms of advantages for left-to-right processing, for head-morphemes and for lexical-stratum. The results are discussed in the context of the Japanese lemma-unit model (Joyce, 2002a, 2002b).

Keywords: Japanese compound words, morphological activation, constituent-morpheme priming paradigm, Japanese lemma-unit model

1. Introduction

At the start of a review chapter on the processing of Chinese compound words, Myers (2006) singles out two factors why the Chinese language deserves the attention of psycholinguistic research investigating morphological processing. The first is his assertion that "Chinese is the poster child of compounding, the language to cite for an example of morphology without much affixation" and, reflecting the considerable influence of Chinese orthography on compound processing, the second is "its notoriously unusual writing system" (p. 169). However, the same basic criteria can also be rallied with substantial justification, to support the claim that the Japanese language also warrants particularly special attention for the insights

DOI 10.1075/bpa.7.11mas

that it can potentially yield towards advancing our understanding of morphological processing.

Indeed, as Joyce and Masuda (2018) essentially corroborate, scholarly portrayals concerning the complexity of the Japanese writing system indicate that it easily surpasses the category of 'notoriously unusual' (see also Joyce, 2011). Moreover, while it is certainly the case that, as an agglutinative language, Japanese possesses various forms of affixation, it is also true that compounding is a highly productive principle of Japanese word formation, involving both 漢語 /kan-go/ Sino-Japanese (SJ) and 和語 /wa-go/ native-Japanese (NJ) morphemes (within glosses, hyphens mark kanji-kanji boundaries; periods mark kanji-hiragana boundaries). Hence, there are a number of Japanese terms that generally correspond to the term of compound word. For instance, although Tamamura (1985) distinguishes between 合成語 /gō-sei-go/ ([combine + form] + word) 'complex words' and 複合語 /fuku-gō-go/ ([multiple (elements) + combine] + word) 'compound words' within his structural classification of Japanese words, he also acknowledges that the terms are often used interchangably. In contrast to these more specialist terms of linguistics, a more generalist term is 熟語 /juku-go/ (mature + word), as in 漢字二字熟語 /kan-ji-ni-ji-juku-go/ 'two-kanji compound word'. While exceptions exist, notably in 熟字訓 /juku-ji-kun/ 'monomorphemic words' orthographically represented by two kanji (e.g., 薔薇 /bara/ 'rose'), in the vast majority of cases, two-kanji compound words correspond to two-morpheme compound words. Essentially, the term is a shorthand convention, from an orthographic perspective, for complex words where, consistent with the morphographic nature of Japanese kanji (Joyce, 2011, 2016), the constituent morphemes are represented by their conventionally-associated kanji (Joyce, 2002a); although, naturally, the degree of semantic transparency between constituent and compound-word meanings can vary (Joyce, Masuda, & Hodošček, 2016; Masuda, 2014). Two-kanji compound words are particularly significant within the Japanese lexicon for a few interrelated reasons. Despite being amongst the simplest possible Japanese polymorphemic words formed by combining two morphemes, there is considerable diversity within their formation principles that encompass approximately nine main relationships (Kageyama, 1982; Nomura, 1988; Tamamura, 1985), they represent the most common Japanese word structure by word-type counts (Joyce, Masuda, & Ogawa, 2014; Nomura, 1988), and, they are, in turn, extremely important building blocks for the formation of longer compound words (Joyce et al., 2014).

As such, the morphological structures, or word-formation principles (WFPs), of two-kanji compound words are unquestionably also of special significance for research into modeling the Japanese mental lexicon, given the need for mental lexicon research to provide some coherent account concerning the representation of morphological information (Feldman (Ed.), 1995; Libben & Jarema (Eds.), 2006; Sandra & Taft (Eds.), 1994; Taft, 1991). And yet, rather surprisingly, even though many visual word recognition studies have used two-kanji compound words as their experimental stimuli (e.g., Fujita, Ogawa, & Masuda, 2014; Hino, Kusunose, Miyamura, & Lupker, 2017; Hirose, 1992; Ijuin, Fushimi, Patterson, & Tatsumi, 1999; Morita & Saito, 2012; Ogawa & Saito, 2006; Tamaoka, 2007; Tamaoka & Hatsuzuka, 1998), relatively few have specifically considered the WFPs that underlie two-kanji compound words. Thus, the series of constituent-morpheme priming paradigm studies conducted by Joyce (1999, 2002a, 2002b, 2003a, 2003b, 2004) and the two experiments reported in this chapter (some aspects of which have been partially presented at conference in Joyce & Masuda, 2005, 2008, 2009, 2013) are unique in systematically investigating the morphological structures of Japanese two-kanji compound words.

The primary motivation behind Joyce's (2002b) study that utilized the constituent-morpheme priming paradigm with the lexical decision task (LDT) was to investigate the hypotheses proposed by Hirose (1992) based on the results of his own similar experiments. More specifically, Hirose's experiments contrasted LDT reaction times (RTs) for two-kanji compound word targets across three prime conditions of first-constituent, second-constituent and unrelated kanji. His basic findings were that, while there was significant priming for both constituent conditions compared to unrelated primes, significantly greater priming was also observed for the first-constituent compared to the second-constituent condition. Those results prompted Hirose to hypothesize, firstly, that the lexical retrieval of compound words involves search mechanisms that progress serially from left to right utilizing the first constituent as a retrieval cue, and, secondly, that compound words that share the same first-constituent kanji are represented together within clustered arrangements. Notwithstanding the waning influence of search-based models, such as Forster's (1976) serial search model, since the emergence of connectionist models that assume activation mechanisms, such as McClelland and Rumelhart's (1981) interactive-activation and competition model, from a representational perspective, the notion of clustered arrangements based only on common first constituents would, however, seem to yield some rather odd consequences. For example, it implies that, despite belonging to very different semantic domains, the two NJ compounds of 青空 /ao-zora/ 'blue sky' and 青物 /ao-mono/ 'green vegetables' and the two SJ compounds of 青年 /sei-nen/ 'adolescence' and 青銅 /sei-dō/ 'blue bronze' would all be clustered together based solely on the shared first-constituent of 青 'blue; green' (/ao/ and /sei/ are this kanji's 訓読み /kun-yo.mi/ 'NJ pronunciation' and 音読み /on-yo.mi/ 'SJ pronunciation', respectively, under the system of dual-readings for kanji as explained further later; see also Joyce &

Masuda, 2018). Moreover, such clustering also appears to pose serious problems for capturing the substantial semantic overlap between synonyms from different lexical stratum, such as SJ 登山 /to-zan/ and NJ 山登り /yama-nobo.ri/, both meaning 'mountain-climbing', which would be represented within separate clusters because of the reversed ordering of their constituents.

Thus, Joyce (2002b) sought to replicate Hirose's experiments, but with an additional independent variable that contrasted the morphological structures of the SJ two-kanji compound word targets. The five WFP conditions were (1) modifier + modified (MM), such as 'country' modifying 'road' in 国道 /koku-dō/ 'national road'; (2) verb + complement (VC), such as 'climb' followed by the object 'mountain' in 登山 /to-zan/ 'mountain-climbing'; (3) complement + verb (CV), such as the location noun 'outside' combined with 'eat' in 外食 /gai-shoku/ 'eating out'; (4) associated pair (AP), such as 'man' and 'woman' combined in 男女 /dan-jo/ 'man and woman; men and women'; and (5) synonymous pair (SP), such as two morphemes that both mean 'mountain' combined in 山岳 /san-gaku/ 'mountains'. The independent variable of the prime-target relationship was unchanged with the three conditions of first-constituent, second-constituent and unrelated kanji (as baseline). The study consisted of two experiments; Experiment 1 closely replicated Hirose's (1992) presentation procedure involving a long stimulus onset asynchronicity (SOA) of 3,000 ms, while Experiment 2 adopted a shorter SOA of 250 ms, where a prime was presented for 200 ms followed by an asterisk (※) mask for 50 ms.

Joyce's (2002b) two experiments yielded highly similar results. Similar to Hirose's (1992) results, significantly faster RTs were observed for both constituent-prime conditions across all five WFP conditions in both experiments. However, in sharp contrast to Hirose's results, no significant differences were observed between the two constituent conditions in four of the five WFP conditions; only the VC conditions had significance differences, where first constituents elicited faster RTs than the second constituents. Intrigued at only observing a significant difference between constituent-prime conditions within the VC condition in Joyce (2002b), Joyce (2003a, 2003b) subsequently utilized constituent-morpheme frequency data (Joyce & Ohta, 2002) to calculate positional frequency ratios – how frequently a kanji is either the first or second constituent of two-kanji compound words – in order to contrast low and high positional ratios for the verbal constituents in the reversed WFPs of VC and CV compounds. The results of Joyce's (2003a, 2003b) two further experiments were very similar. In the two high-positional-ratio (HPR) conditions of HPR-V+C and C+HPR-V, the verb-constituents elicited significantly faster RTs compared to the complement-constituents, such that the first-constituents of HPR-V+C elicited significantly faster RTs compared to the second-constituents, while the second-constituents in the reversed WFP condition of C+HPR-V elicited significantly faster RTs compared to the first-constituents. These findings also indicate that the activation of semantic information from the head verb-constituents may be more effective in priming LDT responses to VC and CV compounds. Given that the results from Joyce's (2002b, 2003a, 2003b) experiments are far from compatible with Hirose's hypotheses of search mechanisms that prioritize the first constituent as a retrieval cue, Joyce (2002a, 2002b) proposed the Japanese lemma-unit model (JLUM), which, as outlined in the General discussion, is an adaption of the multi-level interactive-activation framework to the Japanese mental lexicon that draws inspiration from the version for the Chinese mental lexicon proposed by Taft, Liu and Zhu (1999).

This chapter reports on two experiments that also utilize the constituent-morpheme priming paradigm to further explore the morphological activation of two-kanji compound words within the Japanese mental lexicon. More specifically, both experiments seek to examine the early contributions of morphological information by employing a series of very-brief masked SOA conditions. Even though the prime presentation duration of 200 ms used in Joyce's (2002b) Experiment 2 approaches the threshold of conscious attention (Neely, 1977), especially in contrast to Hirose's (1992) long 3,000 ms SOA, the present experiments employ a series of very-brief masked SOAs in order to completely eliminate any possibility of conscious processing of the constituent-morpheme primes. Thus, both experiments investigate whether the influence of morphological information can be detected within the early stages of lexical processing. Moreover, extending on the range of WFP conditions from Experiment 1, which continues to focus on SJ two-kanji compound words, Experiment 2 includes both SJ and NJ compound words. Adding an interesting dimension relating to the different phonological properties of SJ and NJ compounds that more closely approximate the complexities of the Japanese writing system (Joyce & Masuda, 2018), the present experiments provide further evidence for the early contributions of morphological information within the visual word recognition processing of Japanese compound words. The chapter concludes by discussing how the findings from the present experiments are also compatible with the JLUM (Joyce, 2002a, 2002b, 2004).

2. Experiment 1: SJ compound words under brief SOAs

This experiment investigates whether priming effects can be observed at brief SOAs, shorter than the 250 ms SOA employed in Joyce's (2002b) Experiment 2.

2.1 Methods

2.1.1 *Design*

A 4 × 3 × 4 (WFP x prime-type x SOA) three-factor design was used. The four WFP conditions were VC, CV, MM, and SP (the AP condition in Joyce (2002b) was dropped due to difficulties with matching familiarity scores for sufficient target items). The three prime-type conditions were first-constituent, second-constituent, and unprimed (blank, as a more neutral baseline than the unrelated condition used in Joyce (2002b)). The four SOA conditions were 60, 90, 120, and 150 ms. Both the WFP and prime-type factors were within-participant variables, while the SOA factor was a between-participant variable.

2.1.2 *Materials*

As in Joyce (2002b), the stimuli were selected from Joyce and Ohta's (1999) database of 1,000 two-kanji compound words, surveyed for native-speaker ratings concerning the appropriateness of WFP classifications. For each WFP condition, 30 compound words were selected with both classification scores and familiarity scores (Amano & Kondo, 1999) of 5.5 or higher on 7-point scales. The mean classification scores (and standard deviations (*SD*s)) were VC = 6.56 (0.46), CV = 6.48 (0.37), MM = 6.59 (0.33), SP = 6.22 (0.35) and the mean familiarity scores were 5.93 for all conditions (*SD*s: VC = 0.25, CV = 0.27, MM = 0.32, SP = 0.25). Nonword combinations of two kanji were generated from the same database by randomizing second-constituent kanji and 96 items were selected controlling for low 'word-like-ness' ratings.

Notwithstanding Joyce's (2003a, 2003b) findings relating to positional-frequency ratios, which should be interpreted as a form of type frequency related to morphological-family sizes (Schreuder & Baayen, 1997), no attempts were made to control for the token frequencies of the constituent-kanji primes. Given the very high familiarity scores for all compound targets and, particularly, in the absence of any systematic relationships for a given prime across experimental conditions (beyond the WFP conditions being contrasted within the experimental design), implementing such control was deemed both impractical and unnecessary. To counterbalance the compound-word targets over the three prime conditions, three presentation lists were prepared. Participants were assigned evenly to these lists that were randomized for each participant.

2.1.3 *Apparatus*

SuperLab Pro (Version 1.77, Cedrus, San Pedro, CA, USA), running on a personal computer (Power Mac G4, Apple, Cupertino, CA, USA), controlled the presentation of stimuli on a CRT (RD17GXII, Mitsubishi, Tokyo, Japan) and recorded LDT RTs collected via a keyboard. Stimuli at a font size of 36 points were displayed on the computer screen at a viewing distance of approximately 50 cm.

2.1.4 *Procedure*

The procedure was similar to that of Joyce's (2002b) Experiment 2 that used a 250 ms SOA. At the start of a trial, a plus symbol (+) was displayed in the center of the screen as a fixation point for 250 ms. Then, a prime kanji (or blank for the unprimed condition) presented for 40 ms was followed by a mask (※) for 20 ms. In the 60 ms SOA condition, a target compound word was presented immediately after the mask, while in the 90, 120, and 150 ms SOA conditions, a target was preceded by a blank screen for 30, 60, and 90 ms, respectively. A target was displayed until either participants made a lexical decision by pressing a key or a duration of 1,500 ms elapsed. The inter-trial-interval was 1,000 ms. Participants were instructed to press one key (either the 'v' key for left-handed or the 'm' key for right-handed participants) for a compound word and the alternative key for a nonword as quickly and as accurately as possible. The whole experiment, including a practice session of 12 trials, took between 20–25 min to complete.

2.1.5 *Participants*

The participants were 180 undergraduate students of Hiroshima Shudo University, who were assigned across the four SOA conditions, such that each condition had 45 participants. All were native-Japanese speakers who had normal or corrected-to-normal vision and received course credit for their participation. In order to limit the potential effects of speed-accuracy trade-offs, participants who made 20% or more errors for either word or nonword trials were eliminated from the analyses and were replaced by another participant from the same pool.

2.2 Results and discussion

2.2.1 *Overall analyses*

Table 1 presents the mean RTs and priming effects (RT differences from the unprimed baseline condition) (with *SD*s) for Experiment 1 as a function of the SOA and WFP conditions. In the interests of brevity, as Table 1 also presents statistical values (F, p, and η_p^2) for all significant differences observed within the planned comparisons conducted for the participant data, we only describe such differences below. As the data indicate, the patterns of priming effects from first- and second-constituents vary across the WFP conditions. In order to examine the effects of both constituents in each WFP condition, analyses of variance (ANOVAs) were conducted on data for both RTs and priming-effects. Planned comparisons conducted for RTs within both the participant and item data contrasted the RTs for the first- and second-constituent conditions with those for the baseline condition for each SOA condition. Planned comparisons conducted for priming effects contrasted RTs for the first- and second-constituent conditions. Error responses

Table 1. Mean RTs and priming effects (RT differences from unprimed baseline condition) (with *SDs*) for Experiment 1 as a function of the SOA and WFP conditions, together with statistical values (F, p, and η_p^2) for all significant differences observed within planned comparisons conducted for the participant data

SOA	WFP	Reaction times									Priming effct					
		First	$F(1, 44)$	p	η_p^2	Second	$F(1, 44)$	p	η_p^2	Unprimed	First		Second	$F(1, 44)$	p	η_p^2
60ms	VC	553 (93)	10.52	.002	.19	570 (82)				574 (87)	22 (44)	>	4 (56)	5.15	.028	.10
	CV	566 (91)	3.79	.058	.08	561 (86)	5.95	.019	.12	581 (79)	15 (53)		20 (55)			
	MM	565 (88)	4.45	.041	.09	583 (88)				582 (78)	17 (52)	>	−1 (56)	3.35	.074	.07
	SP	538 (85)	20.80	.000	.32	554 (77)	11.47	.002	.21	580 (83)	42 (61)	>	26 (51)	5.45	.024	.11
90ms	VC	569 (85)				580 (75)				582 (92)	12 (53)	>	2 (52)	2.89	.096	.06
	CV	594 (81)				584 (86)				590 (86)	−4 (52)		6 (52)			
	MM	581 (81)	13.84	.001	.23	599 (79)				608 (90)	28 (49)	>	10 (59)	5.91	019	.12
	SP	559 (87)	9.05	.004	.17	565 (77)	6.52	.014	.13	581 (75)	22 (49)		16 (42)			
120ms	VC	544 (83)	5.21	.027	.11	558 (72)				565 (74)	21 (62)		7 (41)			
	CV	570 (76)				557 (77)	9.03	.004	.17	580 (83)	10 (51)	<	24 (52)	5.02	030	.10
	MM	549 (82)	9.44	.004	.18	583 (71)				575 (70)	26 (56)	>	−9 (53)	26.92	000	.38
	SP	533 (72)	26.00	.000	.37	558 (76)	4.70	.036	.10	574 (73)	42 (55)	>	16 (50)	12.97	.001	.23
150ms	VC	539 (59)	4.76	.035	.10	552 (52)				555 (65)	15 (47)	>	3 (46)	3.49	.069	.07
	CV	558 (58)				545 (62)	9.03	.004	.17	569 (64)	11 (47)	<	23 (51)	3.41	.072	.07
	MM	560 (66)				572 (60)				568 (52)	8 (54)		−4 (45)			
	SP	532 (68)	12.96	.001	.23	542 (53)	5.95	.019	.12	557 (59)	26 (47)		15 (42)			

Note. Planned comparisons for RTs compared the two constituent conditions to the unprimed condition and those for the priming effects compared the first-constituent to the second-constituent.

(1,092 data points, 5.06%) were excluded from all analyses and, conforming to common procedures within the literature (e.g., Hino et al., 2017), responses outside the range of ± 2.5 *SD*s calculated from the mean RT for each condition for a given participant were regarded as outliers and adjusted to the relevant cut-off point (295 data points, 1.37%). (Similar ANOVAs conducted for the error-rate data revealed no significant main effect of prime-type, which indicates that the RT data is free from speed-accuracy trade-offs.)

In the 60 ms SOA condition, first-constituent priming effects were significant in all WFP conditions (albeit only marginally so in the CV condition) and second-constituent effects were significant in the CV and SP conditions. First-constituent priming effects were significantly greater than second-constituent effects in the VC and SP conditions, marginally so in the MM condition, but not significant in the CV condition. In the 90 ms SOA condition, first-constituent priming effects were significant in the MM and SP conditions and the second-constituent effect was significant in the SP condition. First-constituent priming effects were significantly greater than the second-constituent effects in the MM condition and marginally so in the VC condition. In the 120 ms SOA condition, first-constituent priming effects were significant in the VC, MM and SP conditions and second-constituent effects were significant in the CV and SP conditions. First-constituent priming effects were significantly greater than second-constituent effects in the MM and SP conditions, but the difference was reversed in the CV condition with the second-constituent effect being significantly greater than the first-constituent effect. In the 150 ms SOA condition, first-constituent priming effects were significant in the VC and SP conditions and second-constituent effects were significant in the CV and SP conditions. The first-constituent priming effect was significantly greater than the second-constituent effect in the VC condition, but the pattern was reversed in the CV condition.

Summarizing across SOA conditions, priming effects were most robust for SP compounds, with priming effects observed for both constituents. That may reflect the substantial semantic overlap between both constituents and the compound word itself. Within MM compounds, although the second constituent is linguistically the head noun, the absence of second-constituent priming compared to some first-constituent priming might be because general nouns tend to be constituents for many compound words. First-constituent priming effects were most visible in the 60 ms SOA condition, but the effects diminished somewhat at longer SOAs, particularly for CV compounds. Moreover, the patterns of constituent priming across SOA conditions were generally reversed for VC and CV compounds words, such that first-constituent priming effects were larger than second-constituent effects for VC compounds, but the trend was reversed for CV compounds, which is consistent with Joyce's (2003a, 2003b) results.

2.2.2 *Focusing on the VC and CV contrast*

In order to further examine that reversed pattern of constituent priming, 2 × 3 (WFP [VC, CV] x prime-type) ANOVAs were also conducted for the RT data at each SOA condition. Again, in the interests of brevity, statistical values for all significant differences observed are presented in Table 2. In the 60 ms SOA ANOVAs, both constituents elicited significant priming in the CV condition, but only the first-constituent effect was significant in the VC condition. In the 90 ms SOA ANOVAs, RTs were faster for the VC condition compared to the CV condition. In the 120 ms SOA ANOVAs, the first-constituent priming was significant in the VC condition, but the second-constituent priming was significant in the CV condition. In the 150 ms SOA ANOVAs, similar to the 120 ms SOA results, the first-constituent priming was significant in the VC condition, but the second-constituent priming was significant in the CV condition.

Summarizing these focused comparisons for the VC and CV compound words, first-constituent priming effects were significantly greater than second-constituent effects for VC compounds across all four SOA conditions. In contrast, for CV compound words, the first-constituent priming effect was only significant in the 60 ms SOA condition, but second-constituent effects were significant in both the 120 and 150ms SOA conditions.

Table 2. Statistical values (F, p, and η_p^2) for all significant differences observed within planned comparisons conducted for the RT data at each SOA condition within the 2 × 3 (WFP [VC, CV] x prime-type) for the participant data (F_1) and the item data (F_2)

SOA	Significant effect	F_1				F_2			
		df	F	p	η_p^2	*df*	F	p	η_p^2
60	Prime-type	2, 88	4.77	.011	.10	2, 116	2.50	.086	.04
	Interaction	2, 88	2.81	.066	.06				
90	WFP	1, 44	7.73	.008	.15				
120	WFP	1, 44	10.93	.002	.09				
	Prime-type	2, 88	4.32	.016	.09	2, 116	3.31	.040	.05
	Interaction	2, 88	4.39	.015	.09				
150	WFP	1, 44	4.98	.031	.10				
	Prime-type	2, 88	5.26	.007	.11	2, 116	4.71	.011	.08
	Interaction	2, 88	3.15	.048	.07	2, 116	3.40	.037	.06

2.2.3 *Discussion*

The more frequent observations of first-constituent priming effects compared to second-constituent effects, particularly in the 60 ms SOA condition, indicate the presence of a left-to-right processing advantage within the constituent-primed activation of compound words. Simply put, in contrast to merely extending on phonological information activated by first constituents, the reversal operation required for second constituents would seem to be more demanding. While acknowledging that it was essentially such an advantage that prompted Hirose (1992) to evoke search mechanisms that prioritize the first constituent as a retrieval cue, supplementing Joyce's (2002b, 2003a, 2003b) earlier results, the results from Experiment 1 that employed a series of brief SOA conditions further undermine such a hypothesis. More specifically, these findings also demonstrate that the patterns of constituent-priming effects vary across WFP conditions, indicating that morphological information is activated early within the lexical processing of two-kanji compound words. In particular, the reversed pattern of constituent-priming for VC and CV compound words also indicates a head-morpheme advantage, where prior presentations of head-morphemes generally elicit larger priming effects. In order to adequately account for such findings, a model of the Japanese mental lexicon needs to represent compound-word structures, as well as the orthographic, phonological and semantic relationships between words and their constituent-morphemes, such as the JLUM (Joyce, 2002a, 2002b, 2004).

3. Experiment 2: Mixed SJ and NJ compound words

As Joyce and Masuda (2018) describe in some detail, one factor that contributes to the complexity of the Japanese writing system is the dual-reading, or dual pronunciation, system of both kunyomi and onyomi associated with kanji. In essence, the core technique by which Chinese characters were adapted to orthographically represent the Japanese language was 訓読 /kun-doku/ 'reading by gloss' (Lurie, 2012), such that the Chinese character 山 meaning 'mountain' became associated with the existing native Japanese morpheme of /yama/ as a kunyomi. However, over time, through the supplementary convention of 音読 /on-doku/ 'reading by sound', onyomi, as SJ approximations of the pronunciations for Chinese morphemes, also became associated with kanji, and so 山 also has an onyomi of /san/. Two-kanji compound words are predominately combinations of SJ morphemes. For example, 大 means 'big' and its onyomi and kunyomi are /dai/ and /ō.kii/, while 学 means 'study' and its onyomi and kunyomi are /gaku/ and /mana.bu/, and when combined as 大学 meaning 'university', the compound word is pronounced by the onyomi of /daigaku/. All the target stimuli investigated in Joyce (2002b) and in Experiment 1 reported here were SJ compound words. However, there are also many two-kanji compound words that are formed as combinations of NJ morphemes, which are pronounced according to their kunyomi. For instance, 雨 means 'rain' and its onyomi and kunyomi are /u/ and /ame/, but when combined with 大 in 大雨 'heavy rain', it is pronounced /ō-ame/ according to the constituent kanji's kunyomi.

Moreover, while a few of the 2,136 official 常用漢字 /jō-yō-kan-ji/ 'characters for general use' have both multiple kunyomi and onyomi, the frequency distribution is generally skewed towards small sets of associated pronunciations, such that 34.7% jōyō kanji only have a single onyomi and no kunyomi (Joyce & Masuda, 2018; Joyce, et al., 2014). Thus, also interacting with kanji usage, which, in turn, reflects their status as either free or bound morphemes, kanji can vary in terms of the association strengths for particular pronunciations, such that, some kanji can be said to be kunyomi-dominant while some kanji are onyomi-dominant. Interestingly, Nomura (1978) has reported faster semantic activation from kunyomi-dominant kanji compared to onyomi-dominant kanji. Although Experiment 2 does not control for the pronunciation dominance of its constituent primes, it compares the patterns of constituent-morpheme priming for both SJ and NJ compound word targets across a range of SOA conditions, as a potentially interesting extension of our investigations into the morphological activation of compound words that further examines the interactions between orthography, phonology and semantics.

3.1 Methods

3.1.1 *Design and materials*

A 5 × 3 × 3 (WFP x prime-type x SOA) three-factor design was used. In contrast to Experiment 1, the WFP conditions for Experiment 2 also included NJ compound words. As examples of NJ-SP and NJ-VC compound words are relatively rare, the five WFP conditions were three SJ conditions of SJ-VC, SJ-CV and SJ-MM compounds and two NJ conditions of NJ-CV and NJ-MM compounds. The three prime-type conditions were unchanged from Experiment 1. Excluding Experiment 1's shortest SOA condition (where the left-to-right processing advantage was most conspicuous), the three SOA conditions were 90, 120, and 150 ms. Again, both the WFP and prime-type factors were within-participant variables, while the SOA factor was a between-participant variable.

Experiment 2 stimuli were also selected from the same database used for Experiment 1. Again, 30 compound words for each of the five WFP conditions were closely matched for both classification and familiarity scores of 5.5 or higher. The mean classification scores (with *SD*s) were SJ-VC = 6.46 (0.38), SJ-CV = 6.31 (0.44), SJ-MM = 6.21 (0.48), NJ-CV = 6.18 (0.35), NJ-MM = 6.32 (0.36) and mean familiarity scores were 5.87 for four conditions and 5.86 for NJ-MM (*SD*s: SJ-VC = 0.08, SJ-CV = 0.13, SJ-MM = 0.10, NJ-CV = 0.18, NJ-MM = 0.22). Similarly, controlling for low 'word-like-ness' ratings, 120 nonword combinations of two kanji were selected.

3.1.2 *Apparatus and procedure*

Both the apparatus and procedure used in Experiment 2 were identical to those employed in Experiment 1.

3.1.3 *Participants*

The participants were 144 undergraduate students of Hiroshima Shudo University; none had participated in Experiment 1. They were assigned across the three SOA conditions, such that each condition had 48 participants. All were native-Japanese speakers who had normal or corrected-to-normal vision and received course credit for their participation. Again, participants who made 20% or more errors on either word or nonword trials were eliminated from the analyses and were replaced by another participant from the same pool.

3.2 Results and discussion

3.2.1 *Overall analyses*

Table 3 presents the mean RTs and priming effects (with *SD*s) for Experiment 2 as a function of the SOA and WFP conditions, together with the statistical values for all significant differences observed within the planned comparisons conducted for the participant data. As with Experiment 1, error responses (1,089 data points, 5.04%) were excluded from the analyses, and a similar treatment of outliers was applied (191 data points, 0.88%). (Similar ANOVAs also conducted for the error-rate data revealed no significant main effect of prime-type, which indicates that Experiment 2's RT data were also free from speed-accuracy trade-offs).

In the 90 ms SOA condition, first-constituent priming effects were significant in all WFP conditions apart from the NJ-MM condition (albeit only marginally so in the SJ-CV condition) but the second-constituent effect was only significant in the NJ-CV condition. First-constituent priming effects were only significantly greater than second-constituent effects in the SJ-MM condition. In the 120 ms SOA condition, first-constituent priming effects were significant in the SJ-VC, SJ-MM and NJ-CV conditions and second-constituent effects were significant in the SJ-CV and NJ-CV conditions. In the 150 ms SOA condition, first-constituent priming effects were significant in the SJ-VC, SJ-MM and NJ-CV conditions, matching the 120 SOA results, and second-constituent effects were significant for all WFP conditions (albeit only marginally so in the SJ-VC, NJ-CV and NJ-MM conditions).

Summarizing across SOA conditions, similar to Experiment 1 results, the patterns of constituent-morpheme priming were generally reversed in the SJ-VC and SJ-CV conditions; although that trend was weaker due to the absence of second-constituent priming in the SJ-CV condition at the shortest 90 ms SOA.

Table 3. Mean RTs and priming effects (RT differences from unprimed baseline condition) (with *SD*s) for Experiment 2 as a function of the SOA and WFP conditions, together with statistical values (F, p, and η_p^2) for all significant differences observed within planned comparisons conducted for the participant data

SOA	WFP	Reaction times									Priming effect				
		First	$F(1, 47)$	p	η_p^2	Second	$F(1, 47)$	p	η_p^2	Unprimed	First	Second	$F(1, 47)$	p	η_p^2
90ms	SJ-VC	587 (94)	4.49	.039	.09	597 (74)				604 (82)	17 (56)	7 (54)			
	SJ-CV	591 (89)	2.95	.093	.06	597 (82)				607 (80)	16 (64)	10 (64)			
	SJ-MM	590 (81)	5.99	.018	.11	607 (81)				615 (83)	25 (69)	> 8 (63)	4.68	.036	.09
	NJ-CV	578 (95)	7.53	.009	.14	586 (73)	4.91	.032	.09	605 (80)	27 (68)	18 (57)			
	NJ-MM	588 (81)				582 (78)				593 (75)	5 (48)	11 (46)			
120ms	SJ-VC	564 (75)	7.60	.008	.14	579 (75)				585 (60)	21 (53)	> 6 (54)	4.76	.034	.09
	SJ-CV	575 (78)				569 (73)	7.07	.011	.13	591 (77)	16 (65)	22 (57)			
	SJ-MM	574 (71)	8.83	.005	.16	587 (79)				594 (67)	20 (45)	7 (48)			
	NJ-CV	554 (80)	12.22	.001	.21	565 (86)	5.00	.030	.10	583 (74)	29 (57)	18 (56)			
	NJ-MM	573 (83)				557 (71)				567 (73)	−7 (65)	< 10 (53)	3.25	.078	.06
150ms	SJ-VC	567 (68)	19.77	.000	.30	576 (63)	6.33	.015	.12	598 (80)	32 (49)	22 (61)			
	SJ-CV	583 (60)				567 (65)	3.71	.060	.07	587 (68)	4 (60)	< 21 (74)	3.73	.060	.07
	SJ-MM	580 (74)	6.69	.013	.12	581 (71)	8.79	.005	.16	606 (72)	25 (67)	25 (57)			
	NJ-CV	548 (78)	16.75	.000	.26	568 (69)	3.63	.063	.07	580 (68)	32 (53)	> 12 (44)	7.48	.009	.14
	NJ-MM	564 (61)				560 (67)	4.03	.051	.08	576 (60)	11 (56)	16 (55)			

Moreover, the patterns of constituent-morpheme priming were somewhat different in the SJ-CV condition compared to the NJ-CV condition despite the shared morphological structure. Finally, as the patterns of priming for the SJ-MM and NJ-MM conditions also seem to differ, we also further examined the contrasts between the SJ and NJ compound-word conditions.

3.2.2 *Focusing on the lexical stratum contrasts*

In order to further examine the lexical stratum contrasts (SJ versus NJ) within the CV and MM compound words, 2 × 3 (WFP [SJ, NJ] x prime-type) ANOVAs were also conducted for the RT data for both WFPs conditions at each SOA condition. The statistical values for all significant differences observed are presented in Table 4.

Table 4. Statistical values (F, p, and η_p^2) for all significant differences observed within planned comparisons conducted for the RT data at each SOA condition within the 2 × 3 (WFP [SJ, NJ] x prime-type) for the participant data (F_1) and the item data (F_2)

SOA	WFP	Significant effect	F_1				F_2			
			df	*F*	*p*	η_p^2	*df*	*F*	*p*	η_p^2
90	CV	Prime-type	2, 94	5.49	.006	.10	2, 116	4.91	.009	.08
	MM	WFP	1, 47	11.48	.001	.20				
		Prime-type	2, 94	2.96	.057	.06				
		Interaction	2, 94	2.76	.068	.06				
120	CV	WFP	1, 47	5.11	.028	.10				
		Prime-type	2, 94	8.40	.000	.15	2, 116	6.37	.002	.10
	MM	WFP	1, 47	20.29	.000	.30	1, 58	4.06	.049	.07
		Interaction	2, 94	4.64	.012	.09	2, 116	4.02	.021	.06
150	CV	WFP	1, 47	9.56	.003	.17				
		Prime-type	2, 94	5.74	.004	.11	2, 116	3.70	.028	.06
		Interaction	2, 94	5.09	.008	.10	2, 116	3.13	.048	.05
	MM	WFP	1, 47	20.47	.000	.30	1, 58	4.05	.049	.07
		Prime-type	2, 94	5.40	.006	.10	2, 116	6.19	.003	.10

The results for the two CV WFP conditions were as follows. In the 90 ms SOA ANOVAs, both constituents elicited significant priming in both the SJ-CV and NJ-CV conditions. Similarly, in the 120 ms SOA ANOVAs, both constituents elicited significant priming in both WFP conditions. In contrast to the 90 ms SOA, however, RTs were faster for the NJ-CV condition compared to the SJ-CV condition. In the 150 ms SOA ANOVAs, only the second constituent elicited significant priming in the SJ-CV condition, but only the first constituent elicited significant priming in the NJ-CV condition.

The results for the two MM WFP conditions were as follows. In the 90 ms SOA ANOVAs, only the first constituent elicited significant priming in the SJ-MM condition and no differences were observed in the NJ-MM condition. Similarly, in the 120 SOA ANOVAs, only the first constituent elicited significant priming in the SJ-MM condition and no differences were observed in the NJ-MM condition. In the 150 ms SOA ANOVAs, both WFP and prime-type effects were significance, such that both constituent conditions elicited significant priming in both the SJ-MM and NJ-MM conditions, and RTs were faster for the NJ-MM condition compared to the SJ-MM condition.

Summarizing these focused comparisons, while a reverse trend was observed in the 150 ms SOA condition, such that only the second constituent elicited faster RTs in the SJ-CV condition and only the first constituent elicited faster RTs in the NJ-CV condition, both constituents elicited faster RTs in the other combinations of SOA and WFP conditions. For the MM conditions, the results were more complicated, in that all first-constituent priming effects were significant for the NJ-MM conditions across all SOA conditions, but first- and second-constituent priming effects were only observed in the SJ-MM and the NJ-MM conditions in the 150 ms SOA condition.

3.2.3 *Discussion*

Expanding on the range of WFP conditions by including both SJ and NJ compound words, Experiment 2 provides further evidence for the early activation of morphological information within the processing of compound words. More specifically, in addition to providing further support for the advantages of left-to-right processing and of head-morpheme observed in Experiment 1, with its wider variety of WFP conditions, Experiment 2 also provides evidence of a lexical-stratum advantage. There would seem to be two aspects to this advantage. The first is the phonological match between first-constituent primes and the initial pronunciation of NJ compound words, and the second aspect is that, as the constituents of NJ compound words tend to be kunyomi-dominant, the constituent-primed processing of NJ compounds may also benefit from the faster activation of semantic information from such primes compared to onyomi-dominant kanji (Nomura, 1978).

4. General discussion

In order to further investigate the morphological activation of two-kanji compound words, the two experiments reported within this chapter employed a series of very-brief masked SOA conditions with the constituent-morpheme priming paradigm. Extending on the findings of Joyce's (2002b, 2003a, 2003b) studies, the present experimental results provide evidence for complex interactions between different forms of morphological information across the different WFPs. The three processing advantages observed within the results – the left-to-right processing advantage, the head-morpheme advantage and the lexical stratum advantage – are intricately intertwined with the complex interactions between orthography, phonology and semantics underlying the complicated nature of the Japanese writing system (Joyce & Masuda, 2018).

Prima facie, the left-to-right processing advantage could be interpreted in terms of orthographic information. Even though the point should be self-evident, it is worth stressing that for two-kanji compound word targets within the constituent-morpheme priming paradigm, there is always an orthographic overlap between the constituent prime and one of the target's constituents; only its position varies. However, while it is true that first-constituent priming effects were more frequently observed than second-constituent effects, if the left-to-right processing advantage were purely a matter of orthographic overlap, then, one would expect this advantage to be even more prominent across the WFP and SOA conditions. Moreover, the significantly greater second-constituent priming effects for CV compounds in both the 120 and 150 ms SOA conditions of Experiment 1, in particular, suggest that the observed constituent-priming effects are also partially semantic in nature.

As hinted already, the activation of phonological information is potentially a factor underlying both the left-to-right processing and the lexical-stratum advantages. Both advantages could reflect the varying combinations of phonological ordering and overlap intervening between the constituent-morpheme primes and the compound word targets. In terms of the left-to-right processing advantage, the processing entailed in merely extending on the onyomi activated by the first-constituent primes of SJ compound words would seem to be less burdensome that the reversal operation necessary for the onyomi activated by second-constituent primes. Similarly, the lexical-stratum advantage, as manifested in the significant main effects of WFP between the NJ-CV and SJ-CV conditions within Experiment 2, could be reflecting the phonological match between kunyomi-dominant constituent kanji and NJ compound words. One must, however, be wary of attempting to account for all of the observed constituent-morpheme priming effects purely in terms of the phonology activated by constituent-primes, especially, when the activated phonology is not always consistent with the phonology of the compound word targets (i.e., kunyomi-dominant constituent primes to SJ compound word targets).

Moreover, a number of the observed constituent-priming effects seem to strongly indicate the early activation of semantic information. In particular, the most robust priming effects for both constituents were observed in the SP condition in Experiment 1, where the semantic overlap between the meanings of both constituents and the meaning of the compound word itself is always substantial, such as 山岳 where both constituents mean ‘mountain’ and the compound word means ‘mountains’. Similarly, the overall trend towards greater constituent-priming effects from the verbal constituents of the reversed WFP conditions of VC and CV compound words across the two experiments also indicates greater degrees of semantic similarities between the meanings of the verbal constituents and the compound word meanings.

As noted within the Introduction, Joyce (2002a, 2002b) has proposed JLUM as a model of the Japanese mental lexicon that is capable of providing a plausible account of the constituent-primed lexical processing of two-kanji compound words. Part of the model is depicted in Figure 1. JLUM has a close affinity with the multi-level interactive-activation framework that Taft has been developing for some time, from his (1991, 1994) initial extensions of McClelland and Rumelhart’s (1981) model by incorporating word-body and morpheme-level representations, respectively, to the AUSTRAL version (Taft, 2015) for the English mental lexicon, as well as applications to the Chinese mental lexicon (Taft et al., 1999; Taft & Zhu, 1995, 1997). However, JLUM was most directly inspired by Taft et al.’s (1999)

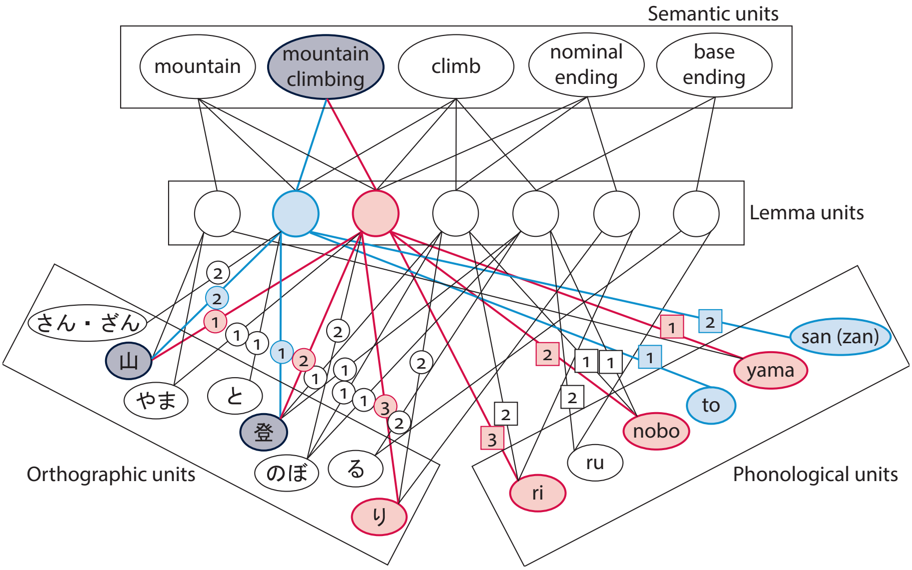

Figure 1. Part of the JLUM representations for the synonymous SJ 登山 and NJ 山登り compound words for ‘mountain-climbing’ (Adapted from Joyce’s (2002a: 89) Figure 1 to specifically highlight the lemma-unit representations of these synonyms, the figure omits lower-level orthographic and phonological representations and although constituent ordering is indicated by numbers on some links, that is actually assumed to be a lemma-unit property)

Chinese version that first incorporated lemma-unit representations as connections or way-stations mediating the links between both orthographic and phonological access representations and semantic representations. That modification was proposed as an effective solution to issues associated with earlier Chinese versions (i.e., Taft & Zhu, 1997) relating to representational redundancy, homographs and semantic transparency. Given that they are all vexing issues for earlier Japanese models, such as Saito's (1997) companion-activation model and Tamaoka and Hatsuzuka's (1998) model, the inclusion of lemma-unit representations is also well-motivated for models of the Japanese mental lexicon.

However, an even more distinctive feature of the JLUM is that it is the first model of the Japanese lexicon that unifies the processing of the Japanese writing system's multi-scripts within a single integrated model. A fundamental challenge for any comprehensive model of the Japanese mental lexicon is to model the connections between the Japanese writing system's multi-scripts and meaning, particularly, given the pervasive nature of orthographic variation (Joyce, 2004; Joyce, Hodošček, & Nishina, 2012; Joyce & Masuda, 2018). JLUM's lemma-unit representations also provide an elegant solution to that dilemma, as it is far simpler to extend the range of orthographic representations linking directly to the relevant lemma units, such that the kanji 山, the hiragana やま, the katakana ヤマ and the alphabetic representation *yama* can all be linked to the meaning of 'mountain' via its lemma unit. JLUM is also able to more realistically model the nuances of kunyomi and onyomi usages. Although rote-learning of the distinctions is an integral aspect of kanji instruction in school, knowledge of these readings within the adult native-speaker can also be assumed to be greatly dependent on usage frequencies, as reflected within the network of links from phonological access representations to lemma units.

As implied already, a core motivation for proposing JLUM was its potential to provide a more plausible account of the results from the constituent-morpheme priming paradigm that demonstrate priming effects for both constituents (Joyce, 2002a, 2002b). Unlike Hirose's (1992) hypotheses that evoked search mechanisms with a pivotal retrieval-cue role for the first constituent, JLUM assumes mechanisms of spreading activation as underpinning the lexical retrieval of two-kanji compound words. More specifically, it assumes that two-kanji compound words are activated via activation that passes in parallel from both orthographic representation units for its constituent kanji to the compound word's lemma unit. Moreover, constituent-morpheme priming effects are explained by assuming that lingering activation within the network of lemma units linked to the orthographic units of constituent kanji provides those lemmas with an advantage over other units, and, thus, the lingering activation leads to faster RTs compared to unrelated or unprimed lexical access. Figure 1 illustrates part of JLUM, highlighting the representations for the synonymous SJ 登山 and NJ 山登り compound words. While both compound words are assumed to activate the meaning of 'mountain-climbing', their lexical status as independent words is represented by the separate lemma units. While the SJ compound word 登山 and its onyomi of /to-zan/ would be activated when the constituent kanji of 登 /to/ and 山 /san (zan)/ are combined together as SJ morphemes in that order, the NJ compound word 山登り and its kunyomi of /yama-nobo.ri/ would be activated when the compound word is a combination of the NJ morphemes of 山 /yama/ and 登り /nobo.ri/, respectively.

Finally, we conclude by acknowledging some concerns relating to the reported experimental results that point to some issues that will be addressed within future research. The first concern is that the observed constituent-morpheme priming effects were not constant across the various WFP and SOA conditions over the two experiments. One point that warrants stressing in that context is that although both experimental designs consisted of SOA conditions that manipulated the interval between prime-stimulus offset and target-stimulus onset – ranging from 60, 90, 120 to 150 ms over both experiments – for all SOA conditions, primes were only presented for 40 ms followed immediately by a mask for 20 ms. And yet, even with such minimal presentation durations, significant priming effects (albeit only marginally so in a few cases) were observed in 58% of the experimental conditions (with 58% and 42% of those from the first- and second-constituent conditions, respectively). Moreover, the general trends within these results are highly consistent with the results previously reported by Joyce (2002a, 2002b, 2003a, 2003b, 2004). A second concern relates to the WFP conditions, and although they were controlled for based on Joyce and Ohta's (1999) database of WFP classification scores, the differing trends within the priming effects for SJ-CV and NJ-CV, in particular, suggest that more detailed analyses of the morphological structures of Japanese compound words could be beneficial for future constituent-morpheme priming experiments. A third possible concern is that, given morphological processing has been shown to be influenced by the degree of semantic transparency, or associations, between constituent and compound word meanings (Libben, 2006; Sandra, 1994), future priming studies will also utilize the database more recently compiled by Masuda and colleagues that has surveyed the semantic relatedness of compound word constituents (Joyce et al., 2016; Masuda, 2014; Masuda, Joyce, Ogawa, Kawakami, & Fujita, 2014). While these concerns are closely related to the complexities of the Japanese writing system's multi-scripts, and, thus, undeniably pose some special challenges for conducting constituent-priming investigations into the morphological activation of Japanese compound words, as the reported experiments demonstrate, such studies can also yield some potentially interesting insights into the richness of morphological processing.

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