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Word or morpheme? Investigating the representation units of L1 and L2 Chinese compound words in mental lexicon using a repetition priming paradigm

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ABSTRACT

The present study used a repetition priming paradigm to investigate the basic morphological units stored in mental lexicon for Chinese as second language learners (L2) and Chinese native speakers (L1). Meanwhile, the modulation of Chinese morpheme property (bound or free) in lexical processing was examined. The results revealed that for intermediate-level L2 learners, Chinese words could be accessed through either whole-words or morphemes, while advanced-level learners and Chinese natives might employ a whole-word pathway. This might suggest that as language proficiency and reading experience develops, learners tend to rely more on whole-words as a processing strategy. Regarding the morpheme property effect, bound morphemes reported a greater priming effect than free morphemes in lexical decision tasks for both L1 and L2 speakers, which was interpreted with an interactive-activation framework.

KEYWORDS

Representational units; L2 Chinese; morpheme property; repetition priming

Since Treisman (1960) first proposed the notion of mental lexicon, a faculty in human's brain consisting of massive vocabulary with different cognitive thresholds, extensive research has been conducted to examine how lexical information was represented in mental lexicon. Increasing empirical evidence across a variety of languages including English (Feldman 1992), Chinese (Zhang and Peng 1992; Peng, Li, and Liu 1994), Hebrew (Frost et al. 2005), Russian (Kazanina et al. 2008), Spanish (Andoni Dunabeitia, Perea, and Carreiras 2008), Arabic (Abu-Rabia and Awwad 2004), Italian (Burani and Caramazza 1987), and Dutch (Zwitserlood 1994) demonstrated three models regarding the morphological units stored in mental lexicon, that is, whole-word/full word position (Colé, Beauvillain, and Segui 1989; Manelis and Tharp 1977), decomposition/morpheme position (Taft and Forster 1975), and hybrid representation model (Caramazza, Laudanna, and Romani 1988; Colé, Segui, and Taft 1997; Fehringer 2012). The three models were also further applied to interpret second language data, most of which focused on English as an L2 (Frost et al. 2005; Silva and Clahsen 2008).

What is not yet clear is whether words from non-alphabetic language (e.g., Chinese) are presented holistically or compositionally in L2 mental lexicon. Particularly, little study addressed this issue from a comparative lens (L1 vs. L2) and developmental perspective (higher vs. lower proficiency). In addition, little of previous research examined the morpheme property effect for L2 Chinese, while it was believed to modulate Chinese L1 lexical representation (Taft and Zhu 1995). As a response,

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the current study aims at investigating the lexical representation units for both L1 and L2 Chinese speakers across various proficiency levels, as well as the morpheme property modulation in Chinese lexical processing.

Lexical representation in English

The investigations into representational units, which started with alphabetic languages, were also termed "morphological structures" (Colé, Beauvillain, and Segui 1989), "units of representation" (Burani and Laudanna 1992), "morphological units" (Boudelaa and Marslen-Wilson 2001), or "storage units" (Chen 2011). This issue deals with how words (especially complex words) are stored and processed in mental lexicon, whether in their whole forms or corresponding decomposed constitutes. Osgood and Hoosain (1974) examined the recognition thresholds for English words, morphemes, trigrams, and noun phrases, whose findings supported that the word as a linguistic unit had a special salience in language comprehension. Salience of English word as a basic unit in language processing was signified through its relative dominance over morphemes and phrases in human language faculty. A *whole-word/full word position* was subsequently proposed that each word might be stored as an independent entry in mental lexicon and accessed through its holistic form, while the role of constitute morpheme is limited. The hypothesis was also supported by results from L2 English perception (Silva and Clahsen 2008), L2 Spanish recognition (Zyzik and Azevedo 2009) and L1 English word production experiments (Aitchison 2012).

On the other hand, Taft and Forster (1975, 1976) found that both prefixed words and polymorphemic words were decomposed into morphemes before lexical access processes, thus establishing a *decomposition/morpheme position*. Morpheme rather than whole-word was thought to be the basic unit for lexical storage and retrieval. Existing evidence tended to show that morphological decomposition was a necessary or even obligatory pathway in recognizing target English words for both L1 (Taft and Forster 1976; Bergman, Hudson, and Eling 1988; Zwitserlood 1994; Rastle et al. 2000) and L2 population (Frost et al. 2005; De Grauwe et al. 2014; Kim and Wang 2014; Liang and Chen 2014; Safak 2015; Alonso, Baquero Castellanos, and Müller 2016; Li, Jiang, and Gor 2017; Uygun and Gürel 2017).

Furthermore, integrating the aforementioned models, a *hybrid model* holds that morphemes do play a crucial role in lexical access, yet not obligatory (Sandra 1990; Marslen-Wilson et al. 1994; Zhou and Marslen-Wilson 1995). Instead, both decomposed and holistic forms of the acquired vocabulary are equally stored and retrieved in mental lexicon, which interacts with various lexical property factors such as frequency, morpheme status (base form and free form), semantic transparency and morphological complexity (Colé, Segui, and Taft 1997; Fehringer 2012). To further specify the inner organization of a hybrid model, Taft (1994) proposed an Interactive-Activation Model, which argued that whole-words and morphemes were represented in different layers of mental lexicon and could be activated interactively. More recently, a large and growing body of literature also reported a hybrid pattern in L2 English lexical processing among a variety of L1 backgrounds, such as Turkish-Dutch bilingual children (de Zeeuw, Schreuder, and Verhoeven 2015), Chinese-speaking English learners (Liang and Chen 2014; Deng et al. 2017), Greek speakers of ESL (Voga, Anastassiadis-Symeonidis, and Giraudo 2014). As can be seen from the recent developments, representational unit in mental lexicon might not be a binary concept, yet a complex confounding with lexical and learner factors.

Frequency (word and morpheme frequency) and semantic transparency (transparent or opaque) were the most frequently investigated factors in lexical processing studies (Sandra 1994; Peng, Liu, and Wang 1998; Wang and Peng 1999). Words with high frequency or low semantic transparency were found to be more liable to be processed in whole-word forms relative to their counterparts. Additional lexical factors encompass word length (long or short words), neighborhood size/family size (large or small), familiarity (high or low familiarity to participants), lexical structure (coordination or modification), morpheme property, etc. (see reviews by Myers 2006, 177–183; Jiang 2013, 32). Meanwhile, representational unit is also a typological and developmental issue. A considerable amount of literature discussed the influence of L1 background (Feng and Song 2004; Jiang 2013), age of acquisition (Carroll and White 1973; Morrison and Ellis 2000), and L2 proficiency (Chen and Leung 1989; Liang and Chen 2014).

Lexical representation in Chinese

Typologically, the notion of morphology in Chinese language is distinct from the abovementioned alphabetic languages like English, which heavily relies on prefixes and suffixes for allomorphs and word formations. In Chinese, instead, new words are formed mainly through compounding rather than inflection or derivation, as there is a relatively impoverished morphological system. According to *Dictionary of Usage Frequency of Modern Chinese Words* (Yuan 1990), more than 80% of Chinese words are compounds, composed of two or more constituent morphemes (Zhou et al. 2009). In this account, the findings on morphological units from alphabetic languages might not simply apply to Chinese lexical processing. To examine the uniqueness of Chinese writing system, a number of studies were initiated in the 1990s with Chinese compound words.

Zhang and Peng (1992) firstly investigated the decomposition mechanism in Chinese native speakers' compound word recognition by manipulating word and morpheme frequency as well as lexical structures. They demonstrated that both head and end morpheme frequency of coordinative words (such as 更改, morpheme meanings: alter + change, word meaning: modify) influenced reaction times (RT) to target words, while for modifier words (such as 闹钟, morpheme meanings: alarm + clock, word meaning: alarm clock), only the end morpheme frequency affected the response speed. It was proposed that Chinese words were accessed via character, or decomposed morphemes, in mental lexicon. Similar patterns were obtained by Peng, Zhang, and Liu (1993) using semantic priming paradigm, Zhou and Marslen-Wilson (1994) using auditory stimuli and Peng, Li, and Liu (1994) using a repetition priming paradigm.

On the other hand, the role of whole-words was pronounced in hybrid (Peng, Liu, and Wang 1998; Wang and Peng 2000) and whole-word-based patterns (Tian, Yan, and Bai 2009; Hong and Feng 2010). Peng, Liu, and Wang (1998) found that both surface and cumulative frequency influenced response latencies to Chinese two-morpheme words, based on which an Inter/Intra Connection Model (IIC) was proposed. IIC model held that whole-words and morphemes were represented in the same layer and shared either facilitative or inhibitory relationship mutually. Recently, Tian, Yan, and Bai (2009) and Hong and Feng (2010) suggested that Chinese native speakers relied more on a whole-word pathway than morpheme information in accessing Chinese disyllabic compound words of relatively higher frequency relative to lower frequency.

Empirical evidence on the representation unit for L2 Chinese was rather inadequate and inconclusive. Based on the lexical error data in formal writing production from Vietnamese students learning L2 Chinese, Dong (2011) concluded that Vietnamese learners at the elementary proficiency level used mainly whole-word strategies while advanced-level learners relied more on a decomposing mechanism for Chinese compound words.

However, Hong and Feng (2010) obtained the opposite findings while comparing reaction times of Chinese L1 speakers and L2 learners to Chinese compound words under various semantic priming conditions. They found that L2 learners employed more morpheme-level information while L1 speakers tended to demonstrate a whole-word pathway despite that both whole-word and morpheme facilitated word recognition for both groups. For intermediate-level leaners, there was no significant difference between the homographeme priming effect of semantically close relatedness (证明-证实, "prove-verify") and distinct relatedness (主人-主意, "master-idea"). Nevertheless, the priming effect of semantically distinct related homographemes was significantly smaller than the close ones for advanced-level learners, which might indicate an inhabitation effect to semantically close homographemes from the word-level semantic information. The results entailed L2 Chinese learners' transition from morpheme level to word level as language experience develops.

Even though the controversy might result from data source and task design, this indicates a need to examine the interaction between representational unit and L2 proficiency. In addition, it would be interesting to know how lexical property might modulate this process.

Morpheme property

Morpheme property (whether the morpheme could be used as an independent word or not, i.e., free and bound morpheme) effect in lexical processing was evident in L1 English (e.g., Forster and Azuma 2000; McKinnon, Allen, and Osterhout 2003), Japanese (Shimomura 1999), and Chinese (Peng, Zhang, and Liu 1993; Zhou and Marslen-Wilson 1994; Taft and Zhu 1995). Drawing on character naming and lexical decision tasks, Taft and Zhu (1995) suggested that Chinese bound morphemes like 浩 (it means "vast" in compound word 浩荡, "vast and mighty", yet it can't be used alone) could be represented in Chinese native speakers' lexical memory. Shimomura (1999) investigated the role of kanji character property (also called kanji lexicality) in recognizing Japanese compound words using a partial repetition priming paradigm. According to its findings, for Japanese native speakers, bound morphemes (also called nonword kanji character, e.g., 基-基本, meaning: basic-basic) had greater facilitation effects on recognizing target words than free morphemes (also called word type, e.g., 金-金属, meaning: gold-metal).

Nevertheless, so far only one piece of research (Feng and Song 2004) explored L2 Chinese learners' responses to bound and free morphemes. The experiments were conducted in repetition priming conditions among L1 Korean and English groups. Their results revealed that the priming effect of free morphemes was significantly greater than that of bound ones for Korean learners, while there was no bound vs. free morpheme effect for L1 English learners. However, considering the inadequate sample size and lack of reported effect size, the morpheme effect for L2 Chinese deserves a revisit.

To sum up, there has been no solid evidence concerning representational units in mental lexicon for L2 Chinese at different proficiency levels and L2 Chinese relative to L1. Also, what is not yet clear is the impact of Chinese bound and free morphemes on lexical representation units. Evidence from L1 demonstrated the validity of repetition priming paradigm in studying the storage and decomposition of mental lexicon (Peng, Li, and Liu 1994; Wang and Peng 2000; Zhang 2009). Therefore, it might be possible that this pattern can be extended to L2 Chinese learners as well.

Drawing on a repetition priming paradigm, the present study aimed to investigate the representational units for Chinese L1 speakers and L2 learners of intermediate and advanced proficiency levels, as well as the impact of bound/free morpheme property. In this task, the target word is preceded by a prime consisting of the target word itself (whole-word form) or constituent morpheme. Alternatively, a string of neutral symbols (e.g., ####) is used as a baseline to measure the priming effects of whole-words and morphemes (Zhang 2009). If morphemes (or Chinese characters) and whole-word forms share the similar magnitude of priming effect, which is called full priming pattern, it might indicate that both morphemes and whole-words can be stored and retrieved as independent entries in mental lexicon (Peng, Li, and Liu 1994). Otherwise, it would demonstrate a either morpheme or whole-word representation. We also performed analyses of bound/free morpheme effect for L1 and L2 Chinese and interpreted the data in light of an interactive-activation framework.

Method

Participants

Eighteen native Mandarin-speaking undergraduate and graduate students (10 female) from Beijing Language and Culture University were paid to participate. Thirty-seven students from a variety of L1 backgrounds who studied Chinese as an L2 in Beijing were recruited and divided into intermediate

Table 1. Age, gender, language history and proficiency of three groups.

	Age		Gender	Chinese study (year)			HSK	
	Min	Max	(Male)	Min	Max	Mean	(1–6)	L1 background
Intermediate L2 ($n = 18$)	18	28	4	1.8	3	1.9	3, 4	Urdo: 12, Nepali: 6
Advanced L2 ($n = 19$)	18	30	12	3.2	13	6.7	6	Urdo: 2, Nepali: 1, Thai: 5; Russian: 3, English: 3, Arabic: 1, French: 1, Spanish: 1, Kyrgyz: 1, Malay: 1
Native ($n = 18$)	20	29	10	/	/	/	/	Mandarin: 18

and advanced proficiency levels. An adapted Chinese version of Language History Questionnaire (Li, Sepanski, and Zhao 2006) was used to survey students' language background. Exclusion criteria were Japanese and Korean L1 participants, so as to exclude or minimize possible prior character knowledge from L1.

L2 Chinese learners were grouped by placement status[1], years of Chinese study, and HSK scores (Hanyu Shuiping Kaoshi, a standardized L2 Chinese proficiency test). As the result, there were 19 advanced learners (12 female), all of whom had studied Chinese for over 3 years and passed HSK-6; and 18 intermediate learners (4 female), who had a HSK-3 or 4 certification and learned Chinese for 2 to 3 years. Participants' profile was listed in Table 1.

Materials

The key materials were composed of 30 Chinese disyllabic compound words headed with bound morphemes and 30 with free morpheme. The 60 words were selected from the basic and intermediate levels of the syllabus of Chinese vocabulary and characters for different L2 proficiencies (Hanban Examinations 1996), matched on word and character. The criterion for bound/free morpheme was whether this morpheme appeared as an independent word in the basic and intermediate levels of the L2 vocabulary syllabus (Feng and Song 2004). Character frequency and word frequency were extracted from Modern Chinese Character Frequency Database and Modern Chinese Word Frequency Database (Xiao 2010, dataset size: 20 million, www.cncorpus.org/) respectively. To confirm learners' familiarity with the test materials, a five-point Likert scale adapted from the vocabulary knowledge scale (Paribakht and Wesche 1997) was used to test participants' word knowledge among five intermediate-level learners[2]. All the stimuli reported 4.0 or 5.0, indexing a high familiarity. To exclude the potential confounding effects, words were matched on semantic transparency[3], morpheme family size[4], stoke number, part of speech, and lexical structure (for details, see Table 2).

A string of asterisks (****) was used as a symbol prime, whose reaction times would function as the baseline to evaluate the magnitude of morpheme and whole-word priming effects in data analysis. For each target word, there were three prime types: morpheme prime, whole-word prime, and symbol prime. Three prime types were designed in Latin-square among participants.

Additional 60 non-words were created by combining any two Chinese characters arbitrarily and did not make any sense semantically, working as fillers to minimize participants' response strategies. For each participant, 60 keywords and 60 non-words were encountered and one specific target keyword was presented to him or her for only once.

[1]Intermediate: grade 1 and grade 2 students from a Chinese bachelor program, and intermediate class from a Chinese advanced college; Advanced: grade 3 and grade 4 from bachelor program, and postgraduate students in Chinese program.

[2]The five raters were formal participants' classmates, yet not invited to the formal experiment.

[3]Fifteen Chinese native speakers rated on a scale of 1–5 for semantic relatedness between the initial morpheme and the whole-form of 60 keywords where a higher rating indicated a higher semantic transparency.

[4]Family size of the morphemes were calculated by counting the number of words that the morpheme could make up in the basic and intermediate levels of the L2 vocabulary syllabus (Feng and Song 2004).

Table 2. Examples and means of frequency, familiarity, semantic transparency, family size and stroke numbers (standard deviations in parentheses).

		Example		Frequency (per million)		Word familiarity	Semantic transparency		
Morpheme property	Priming type	Prime	Target	Character	Word	(1–5)	(0–5)	Morpheme family size	Stroke number
Free morpheme	Morpheme	天	天气	1224(1377)	509(980)	4.2(0.4)	4.2(0.7)	3.2(2.8)	7.9(3.1)
	Whole-word	天气		/	167(226)				15.1(4.0)
Bound morpheme	Morpheme	足	足球	784(803)	/	4.3(0.5)	3.7(0.7)	3.0(2.2)	7.3(2.4)
	Whole-word	足球		/	214(206)				14.9(3.6)

Note: Example meanings: 天-天气, sky-weather; 足-足球, foot-football.

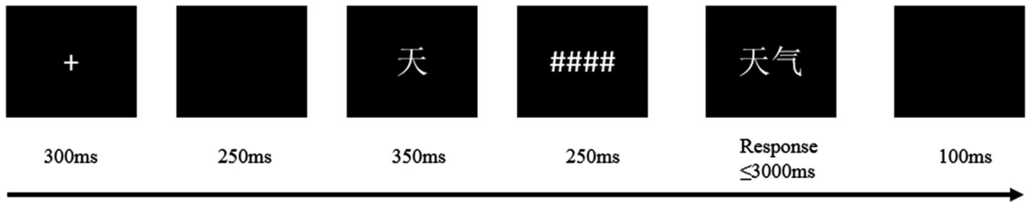

Figure 1. The procedure of lexical decision task in repetition priming paradigm.

Procedure

Participants were tested in a quiet laboratory in the Center for Studies of Chinese as Second Language (CSCSL, BLCU), about 60 cm away from the computer screen with a resolution of 1366 × 768. The visual presentation of stimuli and recordings of responses were controlled by E-prime 2.0 (Psychology Software Tools, Inc., Pittsburgh, PA). In masked repetition priming conditions, a fixation appeared at the center of the screen for 300 ms, followed by a blank of 250 ms. A prime was then presented for 350 ms, followed immediately by a symbol mask, that is, a string of hash signs (####), to avoid participants' strategic effects (Peng, Li, and Liu 1994). After 250 ms, the mask disappeared and the target word was presented until the participant pressed yes or no button on the keyboard or after a threshold of 3000 ms. Participants were asked to decide as quickly and accurately as possible whether the target is an existing Chinese word or not. There was a 100 ms interval between two trials. The experiment started with an oral instruction from the experimenter and 10 trials for practice, accompanied with visual feedbacks to participants' responses. The complete test session for each participant took around 20 min (see Figure 1).

Results

Data from one intermediate and one advanced learner was excluded due to relatively high error rates (>30%). Responses that were either incorrect or two standard deviations away from mean of RT were also excluded (Jiang 2013, 69), which took up less than 5% of the total items[5]. Reaction times for correct answers and error rates in each condition are presented in Tables 3 and 4. They were averaged across priming types, morpheme properties, and language proficiency levels.

A repeated-measure analysis of variance (ANOVA) on RTs was conducted with priming type (whole-word, morpheme, symbol), morpheme property (bound, free), and a between-subject factor language proficiency (intermediate L2, advanced L2, Chinese L1). Results showed that there was a significant main effect for prime type in RT analyses, $F(2,100) = 69.0$, $p < 0.01$, $\eta_p^2 = 0.580$, power = 0.99; pairwise comparisons (with Bonferroni correction) revealed that whole-word priming reported significantly shorter reaction times (778 ± 30 ms) than morpheme priming (861 ± 27 ms), both of which were faster than symbol priming (980 ± 32 ms) ($ps < 0.01$). Free morphemes generated significantly longer reaction time (889 ± 26 ms) than bound morpheme cases (857 ± 30 ms), $F(1, 50) = 8.069$, $p = 0.006 < 0.01$, $\eta_p^2 = 0.139$, power = 0.82. The between-group effect was also significant, $F(2,50) = 22.5$, $p < 0.01$, $\eta_p^2 = 0.474$, power=0.99. Besides, there was a significant priming × language proficiency interaction, $F(4,100) = 4.936$, $p = 0.001 < 0.01$, $\eta_p^2 = 0.165$, power = 0.78. But no priming × morpheme × proficiency interaction was identified. Simple effects analyses were conducted for priming at each language proficiency level (Figure 2).

In intermediate L2 group, both whole-word (1006 ± 52 ms) and morpheme priming (1069 ± 48 ms) reported faster responses than symbol priming (1243 ± 56 ms, $ps < 0.01$), while there

[5]One Reviewer pointed out that results with outliers should also be reported. We did statistical analysis without excluding incorrect responses and reactions times exceeding ±2 standard deviations. The whole result pattern remained unchanged (See Appendix 1).

Table 3. Mean reaction times (in milliseconds, standard deviations in parentheses) across different conditions.

Morpheme property	Free morpheme word			Bound morpheme word		
Priming type	Morpheme	Whole-word	Symbol	Morpheme	Whole-word	Symbol
Intermediate L2	1064(48)	1068(53)	1266(56)	1075(53)	944(58)	1222(62)
Advanced L2	869(46)	742(51)	1041(54)	825(52)	748(56)	967(61)
Native	666(46)	582(51)	707(54)	664(52)	584(56)	680(61)

Table 4. Mean error rates (in percentages) across different conditions.

Morpheme property	Free morpheme word			Bound morpheme word		
Priming type	Morpheme	Whole-word	Symbol	Morpheme	Whole-word	Symbol
Intermediate L2	8.24(1.3)	8.8(1.6)	7.6(1.5)	6.5(1.3)	10(1.2)	8.2(1.8)
Advanced L2	1.1(1.3)	0.6(1.5)	2.2(1.2)	2.8(1.3)	2.2(1.2)	2.8(1.7)
Native	0.6(1.3)	1.7(1.5)	1.1(1.4)	0.6(1.3)	0(1.2)	1.7(1.7)

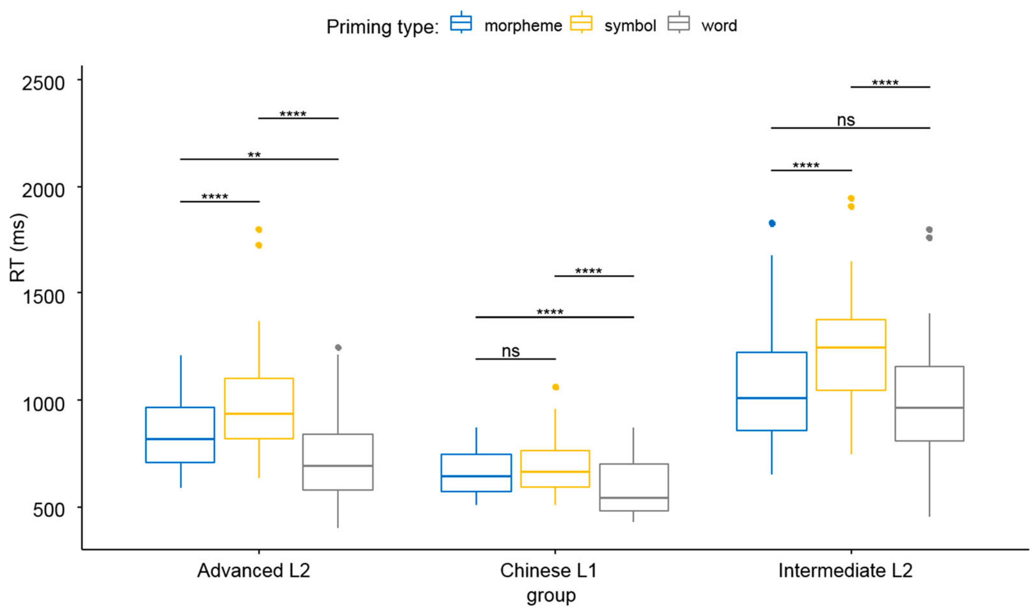

Figure 2. Simple main effect of priming type at different language proficiency groups.

was no significant difference between whole-word and morpheme priming ($p > 0.05$). In advanced L2 group, both whole-word (745 ± 51 ms) and morpheme priming (847 ± 47 ms) reported shorter reaction times than symbol priming (1004 ± 54 ms, *ps* < 0.01); meanwhile, whole-word priming was faster than morpheme priming ($p < 0.01$). For Chinese native speakers, whole-word priming (583 ± 51 ms) was faster than morpheme (665 ± 47 ms) and symbol priming (693 ± 54 ms). Interestingly, there was no difference between morpheme and symbol priming ($p > 0.05$).

A repeated measures ANOVA on error rates revealed a significant main effect for language proficiency, $F(2,50) = 16.1$, $p < 0.01$, $\eta_p^2 = 0.392$. The post hoc tests revealed that native group had lower error rates (*ps* < 0.01), while there was no significant difference between intermediate and advanced L2 learners ($p = 0.739$). There was not any other main effect or interaction.

Discussion

Drawing on a repetition priming paradigm, this study compared the priming effect from whole-word with constitute morpheme in the process of Chinese disyllabic compound words recognition. Reaction time and error rate data were interpreted in light of the dominant priming unit across different language background and proficiency. The examination of Chinese morpheme property effect in lexical representation was also of interest in discussion.

Lexical representation for Chinese native speakers

RT data in the current study showed that for Chinese native speakers, target words primed by whole-word forms were recognized faster than morpheme and symbol priming conditions. The results indicated that whole-word might be more likely to be the optimal unit for storage and retrieval than decomposed morphemes in Chinese compound word access. This finding was in line with the previous evidence (Tian, Yan, and Bai 2009; Hong and Feng 2010) that Chinese native speakers relied more on whole-word information than constitute morphemes in accessing disyllabic Chinese compound words of high frequency.

In light of priming paradigm, repetition priming reflects the effect on target word from the formal and semantic similarities between prime and target. As such, reported smaller effect of morpheme priming relative to whole-word priming might reflect that the activation of morpheme took a longer time than whole-word forms. Current results thus support a whole-word representation model for Chinese native speakers. Chances are that the basic unit for storage and retrieval is whole-word instead of decomposed morphemes in mental lexicon. Each word might have an independent lexical entry.

This line of finding was in contrary to the morphological decomposition position in L1 Chinese studies (Zhang and Peng 1992; Peng, Li, and Liu 1994). Zhang and Peng (1992) found that when word frequency was controlled, the frequency of both constitute morphemes of coordinative words impacted the response latency in lexical decision task, while for modifier words, only the frequency of end morpheme affected the latency. Peng, Li, and Liu (1994) concluded that both whole-word and constitute morpheme priming effects could be found in accessing Chinese compound words given varying semantic transparency at the word level. Nevertheless, even only character frequency (morpheme) on the head position of the compound words was calculated and matched in the current study, all the selected morphemes were of relatively high frequency (>700 per million), and all the target words were of high semantic transparency ($M = 3.97/5$). The possibility could thus be excluded that the discrepancy between the decomposition position and the present study was caused by frequency and semantic transparency effect. It could be inferred that current results index a reliance on whole-word as a processing strategy and economical principle in mental lexicon.

There was yet no significant difference between morpheme and symbol priming (baseline) in the current study. One possible interpretation would be that Chinese compound words with high frequency and high familiarity were stored and accessed totally by their holistic forms, where decomposed morphemes didn't play any role at all (Tian, Yan, and Bai 2009). Yet it could also be due to the limitation of current data quality[6].

Lexical representation for L2 Chinese learners

The priming effects found for L2 Chinese learners indicated differing patterns of lexical representation for intermediate and advanced levels. For intermediate L2 learners, there was no significant difference between whole-word and morpheme priming effect, either of which was stronger than

[6]From one reviewer's comment.

the reference level (symbol priming). The results demonstrated a full priming pattern (Peng, Li, and Liu 1994), where the priming effect on target words from the constitute morpheme was statistically equivalent to the repetitive holistic form itself. Therefore, the pattern provided evidence for the existence of morphemic effect in lexical access (Peng, Li, and Liu 1994) and suggested a hybrid position (Wang and Peng 1999) for intermediate-level Chinese learners. Either word- or morpheme-level information could be used to access the target word, functioning as an available unit for lexical storage and retrieval. One interpretation of the hybrid pattern for L2 intermediate learners was the coexistence of whole-word and morpheme representations at the same layer in mental lexicon (IIC model, Peng, Liu, and Wang 1998). Since words and morphemes shared either facilitative or inhibitory relationship mutually at the same level in light of an IIC model, the priming effect from whole-words and morphemes would make no difference. This single-layer account would be well justified if the priming effect from bound and free morphemes would also make no statistical difference. Otherwise, the equivalent priming effect for whole-word forms and constitute morphemes could be attributable to the multi-layer representations in mental lexicon (Interactive-Activation Model, Taft 1994) where whole-words and morphemes were represented in different layers of mental lexicon and could be activated interactively.

To further explore whether words and morphemes were represented at the same layer of intermediate learners' lexicon, we conducted a follow-up analysis of whole-word and morpheme priming effect (the difference in RT between control and experiment conditions, Feng and Song 2004) concerning bound vs. free morphemes. No statistical difference was observed between the priming effect of morpheme (202 ms) and whole-word (197 ms) in free morpheme conditions for intermediate L2 group; while for bound morpheme words, whole-word priming (278 ms) was significantly greater than morpheme (147 ms). Results showed a morpheme property effect in Chinese compound word recognition, which supported the Interactive-Activation account over IIC model. Because if whole-words and morphemes (both free and bound morpheme) were represented at the same level, there probably would not be a priming difference between free and bound morphemes. Although the previous studies provided evidence for the psychological reality of Chinese morpheme property (Taft and Zhu 1995), the current results extended the bound/free morpheme effect to L2 Chinese learners. Furthermore, we speculate that the division of Chinese bound and free morpheme could affect the morphological units stored in L2 Chinese learners especially for intermediate level.

For advanced L2 Chinese learners, target compound words were recognized faster in both whole-word and morpheme priming conditions than the reference level, which indicated that both word and morpheme information could facilitate the lexical access compared with symbolic priming. However, the priming effect from whole-word was significantly stronger than decomposed morpheme. Therefore, for the L2 Chinese learners, it might be preferable to apply a holistic strategy in lexical access, which was different from the biphasic mechanism (both holistic and decomposing) employed by less proficient learners when processing compound words with bound morpheme. This difference might be caused by learners' familiarity with the target words as well as processing speed in lexical access. As advanced learners might have more lexical knowledge and stronger connections among the sublexical nodes (e.g., phonological and orthographic information) of the target compound words in their lexicon, they probably did not need to decompose the target words into constituting morphemes to access the word meaning (Hong and Feng 2010). Instead, they would directly retrieve the whole-word forms from their mental lexicon without extra decomposing efforts, which is consistent with Chinese L1's strategy.

Together with intermediate L2 data, the current study might imply a shift from a hybrid pattern to a whole-word-reliance pathway in L2 Chinese learners' lexical representation and development. The transition of basic morphological unit in L2 Chinese mental lexicon was also obtained in Hong and Feng's study (2010) in which they compared the priming effect from word- and morpheme-level information between intermediate and advanced L2 Chinese learners. Their results suggested that both morpheme- and word-level information facilitated the compound word recognition by L2

Chinese learners, and that the reliance on the word-level information gradually increased with the development of lexical knowledge and reading skills. The current study added to the previous evidence that Chinese morpheme property played a role in the optimal storage unit of mental lexicon and intermediate L2 learners would probably tend to utilize whole-word information when recognizing compounds with bound morphemes.

Based on our findings, however, the comparison of representational patterns in L2 Chinese learners between different proficiency levels was inconsistent with the conclusions from a previous interlanguage corpus study (Dong 2011). Dong calculated and compared the lexical error rates at word level (e.g., lexical coinage) and morpheme level (e.g., morpheme misuse) of Vietnamese-speaking L2 Chinese learners' written production at different Chinese proficiency levels (initial, elementary, intermediate and advanced). From error rate data, Dong concluded that learners at the elementary proficiency level mainly used whole-word strategies while advanced-level learners relied more on a decomposing mechanism for Chinese compound words. There are some possible interpretations for the discrepancy between Dong (2011) and the current study. First, the definition and calculation of word- and morpheme-level errors were not clear in Dong's report. From her corpus data, even though the biggest proportion of lexical errors for advanced learners was morpheme misuse (19.4%), there were many word-level coinages (13.43%) as well. For initial and elementary levels respectively, morpheme redundancy (adding a third morpheme to the existing dimorphemic word: 20%) and morpheme misuse (22.22%) took up a great proportion of lexical errors. Therefore, there were great chances that word-level representation played an important role in advanced learners' lexicon while morphemic storage and retrieval also modulated elementary learners' lexical development to some extent. The discrepancy could also be caused by the data sources. Dong (2011) utilized the written production data while the current study drew on a recognition task, the underlying mechanism of which might make a difference. Also, since the validity of the self-developed Chinese interlanguage corpus and the operationalization of "L2 proficiency" weren't clearly reported or defined in Dong's study, the homogeneity among different lexical types and proficiency levels could not yet be confirmed. In addition, L1 background in the current study was not well controlled as Dong, which might also contribute to the differentiating patterns.

Furthermore, the proficiency modulation effect in L2 Chinese lexical processing showed a different pattern from L2 English studies (Liang and Chen 2014; Deng et al. 2017) which found that highly proficient Chinese-speaking L2 English learners manifested a rule-based decomposition while less proficient L2 learners relied more on lexical storage. The difference might stem from the typological distinction between Chinese and English. Unlike the massive morphological rules of inflection and derivation in alphabetic languages, the majority of Chinese words are composed of two characters and each of them may function as one constitute morpheme. At the elementary stage of learning Chinese, learners from English background might employ a rule-based decomposing strategy as a result of L1 transfer. As their Chinese knowledge accumulates and automatization to Chinese words increases, chances are that they might rely more on whole-word storage for the high-familiarity words. If we take Chinese native speakers' lexical performance as the ultimate attainment for L2 learners' mental lexicon development, learners could probably start from a decomposing strategy and gradually shift to a whole-word-based pathway. In this account, whole-word forms might be an indicator for native-like proficiency in L2 lexical development.

The role of morpheme property in lexical representation

In the current study, the main effect of morpheme property supported the hypothesis that Chinese bound/free morpheme status, whether it could be used as a word independently or not, has a psychological reality in mental lexicon (Taft and Zhu 1995). Bound morphemes had a greater priming effect on the recognition of target word than free morphemes for both Chinese natives and learners. Such results were in agreement with Shimomura's (1999) findings for L1 Japanese that bound morphemes (nonword kanji character) had greater facilitation effects on recognizing target words than free morphemes (word type).

However, our finding was in contrast to previous L2 Chinese study. Feng and Song (2004) explored the influence of morpheme property (bound or free) and productivity (high or low) on the response latency to Chinese morphemes using a repetition paradigm. For Korean learners of L2 Chinese, the priming effect of free morphemes was significantly greater than bound ones. For English-speaking students, however, although the priming effect of bound morphemes (150 ms) was bigger than free morphemes (108 ms), there was no statistically significant difference. Taking the results from Feng & Song's L1 English group and the current study together, we speculate that the absence of a significant difference on bound/free morpheme in Feng & Song's study might result from different effect sizes between the two studies. Feng and Song (2004) didn't report the effect sizes in data analyses while the effect size for the main effect of morpheme property in the current study was relatively large (i.e., partial $\eta^2 = 0.139$). Accordingly, the Chinese morpheme property effect in L2 Chinese mental lexicon should not be neglected or denied hastily.

The morpheme property effect could be interpreted with an interactive-activation framework (Taft 1994; Shimomura 1999). In this multi-layered model, bound morphemes are stored at the morpheme level while free morphemes have representations at both word and morpheme levels. When participants are exposed to bound morphemes, only nodes at the morpheme level are activated. For free morphemes, however, morpheme nodes would spread facilitatory activation to word-level nodes, while this word-level activation and the morpheme's counterpart at the same level might send inhibitory activation mutually. As a result, the priming effect of free morphemes might be diminished by the inhibition at the word layer.

Conclusion

Our present observations, together with some previous evidence, have yielded a rich picture delineating the characteristics of lexical representation across Chinese L1 and L2 proficiency levels. For Chinese native speakers, the basic unit for storage and retrieval is likely to be whole-words instead of decomposed morphemes in mental lexicon. For intermediate L2 learners, both word- or morpheme-level information could be used to access the target word as available units for lexical storage and retrieval, and the results might be affected by differing Chinese morpheme properties. For advanced L2 learners, it is preferable to apply a holistic strategy, which is different from the hybrid pattern employed by less proficient learners especially when processing compound words with bound morpheme on the head position. Collectively, the current study might imply a shift from a hybrid pattern to a whole-word-reliance pathway in L2 Chinese learners' lexical representation and development.

In addition, the results provided direct evidence that Chinese bound/free morpheme property plays an important role during lexical processing. For Chinese compound words, the priming effect of bound morphemes is greater than free morphemes for both Chinese natives and learners, which could be interpreted with an interactional-activation framework.

There were several limitations warranting discussion. First, as this study failed to manipulate morpheme position as an independent variable, we concede this might include some confounds in data analyses. Another limitation was the absence of elementary Chinese learners' data. Therefore, our data did not holistically depict the L2 lexical development in terms of storage and processing units. Future studies could include the two factors to further explore the difference between L1 and L2 lexicon as well as L2 lexical development.

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Appendices

Appendix 1: Additional analyses without excluding outliers

RT. A 2 × 3 × 3 repeated ANOVA was performed with prime type and morpheme property as within-subject factors, and language proficiency as between-subject factor. There was a significant main effect of morpheme property, $F(1, 50) = 6.75$, $p = 0.012$, $\eta_p^2 = 0.119$; free morpheme (973 ± 33 ms) were responded slower than bound morpheme (922 ± 36 ms). The main effect of prime type was significant, $F(2,100) = 13.71$, $p < 0.001$, $\eta_p^2 = 0.215$, the response time of whole-word priming (861±33 ms) was shorter than morpheme priming (2017 ± 40 ms) and symbol priming (954 ± 40 ms). There was also a significant group effect: native speakers' reaction time was shorter (672 ± 57 ms) than non-native speakers, where advanced L2 learners had significant shorter reaction time (922 ± 57 ms) than intermediate L2 learners (1248 ± 58 ms). The interaction effect between prime type and language proficiency was significant, $F(4,100) = 2.47$, $p = 0.049$, $\eta_p^2 = 0.09$. Follow-up comparisons showed that there was no significant difference between morpheme and whole-word priming ($p = 0.1$) for intermediate learners, while morpheme priming had significant longer reaction time than whole-word priming conditions (*ps* < 0.05). There were no other significant interactions.

Error Rates. There was a significant main effect for language proficiency, $F(1,50) = 43.6$, $p < 0.001$, $\eta_p^2 = 0.466$. Intermediate learners had higher error rates than advanced learners and L1 speakers (*ps* < 0.01), while there was no difference between advanced leaners and L1 speakers ($p > 0.05$).

No other comparisons reached significance.

Appendix 2: Test Materials

Supplementary materials to this article can be found online at https://osf.io/u76t9/