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Effect of Morpheme Meaning Dominance in Compound Word Recognition: Evidence from L2 Readers of Chinese

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Abstract: In reading, rapid and reliable word recognition relies on high-quality representations at both the lexical and sublexical levels, with stable and flexible connections between form, sound, and meaning. Earlier studies suggested that meaning knowledge affects the formation and quality of orthographic representation in language learning, but the impact of morphemic meaning frequency on learners' word recognition was not explored. This research examined second language (L2) Chinese readers' recognition of compound words containing ambiguous morphemes. Using lexical decision tasks in a priming paradigm, we found that dominant primes (i.e., primes with morphemes encoding dominant meanings) facilitated L2 readers' recognition of subordinate targets. We suggested that dominant meanings are associated with higher-quality orthographic representations in learners and dominant primes; thus, they facilitate readers' recognition of orthographically and morphologically related subordinate targets. This study confirmed the role of sublexical constituents' meaning variables in word recognition in language learning.

Keywords: compound word; Chinese; lexical representation; morpheme ambiguity; word recognition

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1. Introduction

A fundamental step in learners' development in reading is to acquire the skill to identify words, which includes form recognition (e.g., decoding the script as words or non-words) and the quick retrieval of meaning and phonological information when a form is presented. Readers' knowledge of a word's form, sound, and meaning and their efficiency in applying such knowledge is reflected as the lexical quality of the word in the reader's mental representation (Lexical Quality Hypothesis, Perfetti, 2007). To achieve reading efficiency, readers' mental representations of words should enable both precise visual decoding and flexible interpretations (Perfetti, 2007, p. 359). Precise decoding requires one to have fully specified and stable orthographic representations of the words or sub-word units; flexible interpretation is needed when one needs to retrieve the appropriate semantic representations of potentially polysemous items within context. In studies on learning to read, the field has ongoing discussions about what affects the preciseness (or the lack thereof) of constituent (i.e., form, sound, and meaning) representations. While Perfetti and Hart (2002) suggested that these constituents are inter-related, the influence of meaning on form recognition was less well understood than the influence of phonology on form (e.g.,

Zhou et al., 2015), and existing studies mostly addressed the constituent relations at the lexical level in only the first language (L1) context.

Second language (L2) learners face more challenges than native speakers in establishing precise and flexible lexical representations. In this study, we were interested in situations where L2 learners face these additive challenges, including limited language experience, complexity in orthographic form, and the needed flexibility in form–meaning mapping. We are also interested in applying the Lexical Quality Hypothesis in sublexical level representations, a less well-studied area in the reading literature dominated by Indo-European languages. For this purpose, we examined Chinese L2 learners' word recognition when compounds contained ambiguous morphemes. We discussed the asymmetries in L2 readers' word recognition performance caused by morpheme meaning dominance and made comparisons to native speakers' performance. Several characteristics of the Chinese writing system and Chinese morphology, as we reviewed below, made the language an appropriate candidate for this inquiry, and this study shed light on the universal aspects of word recognition and reading.

2. Literature Review

2.1. Meaning and Orthographic Representations

The lexical quality of one's word representations is reflected through several representational features: the word's orthography, phonology, morpho-syntax, meaning, and the representation feature of constituent binding. As reading is essentially the rapid and reliable retrieval of meaning, phonology, and other morph-syntactic information from the visual input, orthographic form recognition constitutes the first step in the reading processes. High-quality orthographic representation is "fully specified", and the "letters are constant" (Perfetti, 2007, p. 360). An indication of high-quality orthographic representation is that one can differentiate visually similar forms such as *petty* vs. *pretty* with "precision" and that one can reproduce the print forms accurately (Perfetti, 2007, p. 359). In Chinese, where characters are generally considered the basic writing unit, stroke forms and its positions, radical forms and its positions, and the configuration of these components are all parts of the orthographic representation (Wang et al., 2003, pp. 187, 191). High-quality orthographic representation in Chinese is thus reflected in the ability to recognize the character forms quickly and accurately, to differentiate them from visually similar forms (e.g., 狗 gǒu 'dog' vs. 拘 jū 'to arrest'), and to reproduce the print forms (i.e., handwrite from memory) accurately (e.g., Guan et al., 2011). Meaning representations also vary in their qualities: high-quality meaning representations are "less context-bound", with "fuller range of meaning dimensions available" so that one can differentiate them from semantically similar but non-identical words (Perfetti, 2007, p. 360). One important stipulation of the Lexical Quality Hypothesis concerns constituent binding, i.e., the secure connection among orthographic, phonological, and semantic representations. When these lexical constituents become "well specified in association with another constituent", such a binding is established (Perfetti, 2007, p. 361). In other words, the representation quality of the form, sound, and meaning affects the strength of the links between them. As an example, high-quality meaning representations may facilitate fast and accurate orthographic form recognition.

Studies on the relationship between meaning and form across different languages indicate a causal relationship between semantic information and orthographic learning. First of all, research across different writing systems illustrates the contribution of semantic information to orthographic learning or form recognition. For instance, Quellette and Fraser (2009) reported that presenting semantic information along with novel printed nonwords helped English L1 children's identification of the print words. Subsequently, Quellette (2010) found that pre-exposure to novel English words' semantic information helped chil-

dren to spell correctly more often. Since the ability to recognize and spell print forms accurately is a direct reflection of high-quality orthographic representation, the relevant factor of semantics in learning to spell suggests that semantic information helps children to learn "detailed orthographic representation" (Quellette, 2010, p. 52). Building on earlier literature that demonstrates the role of both semantics and phonology on reading performance, Álvarez-Cañizo et al. (2019, p. 139) investigated whether "these aspects would influence the formation of orthographic representations" among Spanish children. These authors measured the formation of orthographic representation by the reduction in the length effect in a reading-aloud task.[1] Their results showed that "understanding the phonology and meaning [both] contribute to forming a high-quality representation" (p. 138). Their findings were consistent with Suárez-Coalla and Cuetos (2017), who adopted similar training conditions and measures among Spanish L1 adults. Similarly, Zhou et al. (2015) assessed Chinese L1 children's orthographic learning by a reading-out-loud task, since spelling (i.e., writing down) words in Chinese was considered too challenging for their participants, and their results showed both the benefits of phonological pre-exposure and "larger benefits from phonological plus semantic preexposure" (p. 414). Zhou et al. (2015) acknowledged that their results were consistent with the Lexical Quality Hypothesis (Perfetti, 2007; Perfetti & Hart, 2002), suggesting the role of semantics in affecting orthographic representation quality for language-learning children. In other words, evidence from studies of various writing systems indicates the contribution of semantics in establishing high-quality orthographic representations. Another relevant line of research is the role of semantic variables such as concreteness in word identification (See Balota et al., 1991; Pexman, 2012, for reviews). For instance, the recognition and recall of concrete words are consistently faster than abstract words (e.g., Schwanenflugel, 1991). Researchers also established correlations between semantic features of words and word recognition speed or accuracy in L1 Chinese: In Y. Liu et al.'s (2007a) norming study for 2423 Chinese single-character words, the semantic features of the words, including imageability and concreteness, were significant predictors of their naming latencies. These studies illustrated how semantic features may affect other lexical constituents (e.g., phonology) or the strength of links between form, sound, and meaning. Based on these studies, it is reasonable to hypothesize that other semantic variables such as meaning frequencies can lead to differences in learner performances in word recognition.

2.2. Chinese Morphology and Sublexical Representation

The role of meaning in learning to read can be particularly important in languages with deep orthography such as Chinese (e.g., Zhou et al., 2015). Several characteristics of Chinese also make it a particularly informative language to investigate the form–meaning relationships and the role of morphemic ambiguities in foreign language reading. Firstly, it is well acknowledged that visual complexity affects the development of orthographic representations, and Chinese has the most visually complex writing system among 131 orthographies studied by Chang et al. (2016). Chinese also has a large set of characters similar to each other in their visual-orthographic forms. According to Zhang (2012), among 3000 common Chinese characters, 445 sets of characters (e.g., 我 *wǒ* 'me' and 找 *zhǎo* 'search' or 要 *yào* 'want' and 耍 *shuǎ* 'play', etc.) are visually similar to each other. Thus, compared to other languages, the quality of learners' orthographic representation is more likely to be a contributing issue in reading challenges faced by Chinese language learners. Second, Chinese lacks grapheme–phoneme correspondence and has many homophones. These language features lead to high demand for visual-orthographic processing and the need for strong form–meaning links in Chinese reading. In addition, while some existing studies reviewed earlier suggested the role of semantics in affecting orthographic representation at

the word (lexical) level (e.g., Álvarez-Cañizo et al., 2019), few have inquired into how meaning at the sublexical level affects form recognition. The clear morphological boundaries in Chinese, with each character as a physically distinct unit and mapping generally onto one morpheme (e.g., Taft, 2003), add an advantage to morphemic retrieval in lexical processing. Studies in Chinese can therefore fill a gap in form-meaning relationships at the sublexical level. Finally, morphemes are highly productive in forming compounds in Chinese—at least 75% of Chinese words are compounds (X. Chen et al., 2009) and the majority of Chinese characters are ambiguous (Zhao et al., 2003), allowing us to tease apart the impact from form frequency with meaning frequency in our experiment manipulation. Ambiguous morphemes in Chinese are also sometimes referred to as polysemous characters (Xu & Chen, 2022), homographic morphemes (Wu et al., 2017), or homographic–homophonic morphemes (Zhou et al., 1999). The one (form)-to-many (meanings) mapping "break[s] the stability" of the mental representation (Wu et al., 2017, p. 102) and creates additional challenges for language learners in their reading. Investigations into morphemic ambiguities in word recognition in Chinese can thus lead to important theoretical contributions and pedagogical implications in reading.

2.3. Ambiguous Morphemes in Chinese L1 Lexical Processing

We are interested in L2 learners' word recognition and learners' mental representations of ambiguous morphemes in this research. But given the lack of existing research on ambiguous morpheme processing in Chinese L2 reading, we reviewed the most relevant L1 studies below, as their methodologies inform the current investigation.

First of all, there is existing controversy on whether Chinese words involving ambiguous morphemes take the decomposed or whole-word route in processing. Some studies in other languages suggested that whole-word processing may be favored when ambiguous morphemes are involved (Finnish: Bertram et al., 2000a; Dutch: Bertram et al., 2000b). For Chinese, Packard (1999) posited that compounds containing ambiguous morphemes are processed holistically because recognizing words through disambiguating morphemic meanings would be too costly. However, Wu et al.'s (2017) study using event-related potentials (ERPs) found that ambiguous morpheme-sharing Chinese words helped each other in masked priming lexical decision tasks. As such facilitation can only be attributed to morphemic activation, Wu et al.'s study provided evidence that L1 Chinese readers decompose words with ambiguous morphemes during reading.

Several other studies on ambiguous morphemes in word recognition centered around whether such activation is based on shared forms (morpho-orthographic activation) and whether and when morphemic meaning (morpho-semantic activation) is involved. If activation is on the orthographic level, then the target compound would be facilitated by a prime that contains the same character, even when the character takes a different interpretation in the prime than in the target. An example of such a meaning-incongruent pair is 华贵 ('luxurious–expensive') huáguì 'luxurious' and 华侨 ('Chinese–overseas') huáqiáo 'overseas Chinese', where the first morpheme in these compounds shares the same orthographic and phonologic form but not the same meaning. In contrast, if there is morpho-semantic activation, then the competition between the two different meanings of the same form (华) would counteract the orthographic facilitation and may even lead to inhibition. In Zhou et al. (1999), compounds that contain ambiguous morphemes with different meanings (e.g., 华贵 and 华侨) were found to help each other in masked priming and priming with the short stimulus onset asynchrony (SOA, the amount of time that a prime stays visible before the next slide appears) (57 ms). But, when SOA increased to 200 ms, competition at the semantic level led to inhibition.

The effect of meaning dominance in Chinese ambiguous morphemes has been examined by Tsang and his colleagues in a series of studies. Meaning dominance is operationalized as "meaning frequencies" or "the partial frequency of one meaning of an ambiguous word" (Sereno et al., 2006, p. 336). In ambiguous words or morphemes, the more frequently used meaning is referred to as the dominant meaning; it is also the interpretation that would "become available first" when readers are presented with the form (Sereno et al., 2006, p. 336). In contrast, subordinate meanings are more difficult to retrieve than dominant ones (Duffy et al., 1988; Sereno et al., 2006). Tsang and Chen (2013a) found that target compounds with a dominant-interpretation morpheme (i.e., dominant targets) were facilitated by both dominant primes and subordinate primes, whereas subordinate targets were only facilitated by subordinate primes. Those authors argued that, in the dominant-prime condition, subordinate meanings were hard to be activated, but in the subordinate-prime condition, the dominant meaning was pre-activated even though it was not the intended interpretation in the prime. Tsang and Chen (2013a) thus argued that morphemic meaning activation can happen in early stages of word processing, with 40 ms SOA for L1 Chinese readers.

In sum, in the area of morphological processing involving ambiguous morphemes, it remains unclear whether and when morpheme-sharing compounds facilitate each other. It should be noted that the above literature is all based on L1 adult readers, and there was no question that those readers' mental representation of the morpheme's orthography is precise and specified. Thus, the representation quality of the morpheme is not a factor that can affect priming. This differs from the context of the current study, as foreign language learners' orthographic representation of the morphemes may be subject to semantic variables, as suggested by the line of research reviewed earlier (e.g., Álvarez-Cañizo et al., 2019).

2.4. Morpheme Level Representation Among Chinese L2s

The formation of high-quality form, meaning, and sound representations affect learners' abilities to integrate these constituents in reading comprehension (Perfetti & Hart, 2002). Given the above-mentioned challenges in orthographic learning and form-meaning mapping among learners, helping adult L2 Chinese learners establish high-quality form and meaning representations has received considerable attention in the recent decade or so in both the field of reading and second language acquisition (e.g., Guan et al., 2011; Xu et al., 2014). Although there is increasing interest in how lexical properties, including polysemy and semantic transparencies, affect L2 Chinese processing and word learning (see Jiang, 2018, for a review), only a few studies addressed the relationship between sublexical and lexical representations or morphemic ambiguity among Chinese L2s. L. Chen et al. (2018) tested the word superiority effect (WSE) in two-character compounds among Chinese L1 and L2 readers and suggested that L2 readers, with their less well-established character representation, rely more heavily on word knowledge or a top-down approach in word recognition, compared to L1 readers. More recently, Xu and Chen (2022) investigated how morpheme status (bound vs. free morphemes) and polysemy affected compound word recognition among Chinese L2 learners. Using a lexical decision task, the researchers reported a marginal advantage for polysemous morphemes in contrast to monosemous ones in lexical decision tasks of compounds. That study was one of the first that found a contribution from morphemic meaning variables to word recognition among Chinese L2 learners.

From the perspective of teaching and learning, it is especially important to investigate the factors affecting morphemic representation quality through word recognition. In Chinese vocabulary learning, practitioners noted a 识词不识字 ('knowing words but not characters in the words') phenomenon that echoes L. Chen et al.'s (2018) concerns regard-

ing learners' poor character representations in compounds. Yang and Fu (2014) observed that students' error rate in mispronouncing a character in isolation was much higher than in mispronouncing it in compounds; further, students often fail to recognize or misread a constituent character in a familiar compound when it appears in a different compound combination (Yang & Fu, 2014; Wu, 2000; Zhao, 2012). For instance, while students can read 结婚 *jiéhūn* ('tie–marriage'; 'get married') they could not read 婚 in 婚礼 *hūnlǐ* ('marriage–ceremony') or would misread the compound as *结礼 ('tie–ceremony'). These errors indicate that even when learners achieved form-sound-meaning mapping at the compound word level, their constituent representation and binding at the morpheme level remain weak and unstable. Note that the 识词不识字 phenomena cannot be purely attributed to learners' lack of morphological awareness, because morphological awareness develops with students' proficiency levels but 识词不识字 continues to challenge intermediate (Yang & Fu, 2014) and advanced level learners with more than 800 hours of formal learning (Wu, 2000). A better understanding of the factors affecting L2 learners' morpheme representations quality can help advance pedagogies that alleviate learners' difficulties in this area.

The above review suggests several gaps in form–meaning interactions in sublexical representations in the language learning context. The present study attempted to fill these gaps by exploring the impact of meaning dominance of ambiguous morphemes in word recognition among Chinese L2 readers. Our goal was to investigate form–meaning interactions when such constituent associations are being formed in the course of foreign language learning. In particular, we investigated if meaning dominance in ambiguous morphemes affects Chinese L2 readers' recognition of compound words, and if so, in what ways.

3. Methods

3.1. Participants

Twenty Chinese L2 learners from a university in Southern China participated in the experiment (8 females; average age: 22.75; *SD* = 7.0). All participants were native speakers of Korean. At the time of the experiment, these participants had learned Chinese for at least two years in an intensive program with 20 contact hours per week. Eleven participants reported that they had passed HSK 5 (the Fifth Level of the Chinese Proficiency Test, with a required vocabulary bank of 2500 words), and the other nine participants had passed HSK 6 (the Six Level of the Chinese Proficiency Test, with a required vocabulary bank of 5000 words) (Hanban Examinations, 2001).

While the focus of our study was the effect of morpheme meaning dominance in compounds in L2 reading, we included an L1 control group to probe potential differences between L1 and L2 patterns. For the L1 group, 23 college students who were Chinese native speakers (14 females; average age: 20.83; *SD* = 2.15) were recruited from mainland China. All L1 participants were fluent in spoken and written Chinese.

3.2. Stimuli and Design

Our experimental items were two-character compounds that contain ambiguous characters. The compounds themselves were unambiguous at the word level. We chose 22 ambiguous characters from the textbooks that the L2 participants had studied. All characters have at least two distinct meanings in The Contemporary Chinese Dictionary (Chinese Academy of Social Sciences, 2016). For each critical character (e.g., 光 *guāng*), we constructed a pair of compounds that contain the character: one compound (e.g., 光明 *guāngmíng*, 'bright') is related to the character's dominant meaning (e.g., 'light'), and the other compound (e.g., 光临 *guānglín*, 'presence of honorable guests') is related to the character's secondary or subordinate meaning (e.g., 'honor').

To construct word pairs for each critical character, we conducted the first stimuli assessment study. We presented the list of 22 characters to 34 Chinese native speakers who did not participate in the main experiment and asked them to write down the first meaning for each character that came into their minds. Participants were allowed to write down the word that included the character if they thought the meaning of the character was difficult to describe.

To identify the dominant meaning for each of the 22 characters, we aggregated all meanings provided by the participants. The coding of the meanings provided was conducted by the two authors, who are experienced Chinese linguists. The two authors first coded all responses independently, identifying the most frequently reported meanings for each character. Inter-rater reliability was high, with discrepancies in 3 out of the 748 responses. These discrepancies were resolved through discussion. In consultation with the literature (e.g., Tsang & Chen, 2013b; Sereno, 1995), we determined that a dominant meaning should be the most frequently reported meaning for a character and should be reported at least 30% of the time.[2] A total of 3 of the 22 characters did not have a "dominant" meaning that meet the criteria, and these 3 characters were excluded from our final analysis. To construct dominant words with each of the remaining 19 characters, we chose two-character compounds that include the character with its dominant meaning.

We then identified a subordinate meaning for each character. In most cases (14 of the 19 characters), the subordinate meanings were selected from non-dominant meanings provided by the participants in the stimuli assessment. For the remaining five cases, we selected a non-dominant meaning from Chinese Academy of Social Sciences (2016) because the subordinate meaning provided by the participants did not have a two-character compound that fit the orthographic complexity and word frequency criteria. (See the next paragraph for these criteria). The average percentage of dominant meaning in our stimuli assessment study was 70% (ranging from 32% to 97%, *SD* = 19%). For the 14 characters assigned a subordinate meaning from participant responses, the average percentage of subordinate meaning was 9% (ranging from 0% to 27%, *SD* = 8%). The average percentage difference between dominant meaning and subordinate meaning was 61% (ranging from 6% to 97%). The average percentage difference adhered to norms in Tsang and Chen (2013b) and Sereno (1995).

To create dominant and subordinate word pairs that can establish a comparison, we made sure that the critical character was always in the first constituent position of both primes and targets, and each word pair was controlled for orthographic complexity and word frequency. To ensure that all words in the experiment conditions were transparent, a second stimuli assessment study was run, with 12 Chinese native speakers recruited as participants. (These participants were not from the same pool of participants who took part in the first stimuli assessment.) Participants were asked to rate whether the key character contributed to the meaning of the whole word on a 6-point Likert scale, with higher ratings indicating stronger contributions. The mean ratings for words in the dominant and subordinate meaning words were 5.60 (*SD* = 0.54) and 4.54 (*SD* = 0.54), respectively.

In addition to the 38 words representing two meanings for each of the 19 characters, we selected 36 words that do not share a character or related meaning (严格–补充 'strict'–'to supplement') to constitute materials for the control condition. Those words constituted 36 pairs in total (with 严格–补充 and 补充–严格 considered as two pairs). Table 1 illustrates how stimuli in the dominant, subordinate, and control conditions are matched. All words in the experimental material had occurred in L2 participants' textbooks. The characters and their dominant and subordinate words, which constituted our key study materials, are listed in Appendix A.

To test the influences of meaning dominance of ambiguous morphemes in word recognition, we had three experimental conditions. In the dominant condition, words with the dominant meaning served as prime while the words with the subordinate meaning as the target (prime–target: 光明–光临 'bright'–'presence of honorable guests'). In the subordinate condition, words with the subordinate meaning were the primes, and words with the dominant meaning were the targets (prime–target: 光临–光明 'presence of honorable guests'–'bright'). The third condition was the control condition, in which the prime word and the target word did not share a character or related meaning (prime–target: 严格–补充 'strict'–'to supplement'). If the meaning dominance of characters impacts word recognition, we expected that participants' performance in the two experimental conditions (dominant condition and subordinate condition) would show different patterns, respectively, when compared with the control condition. It should be noted that to accommodate the participants' proficiency level, we were limited to a small set of words containing ambiguous morphemes. Thus, we adopted a between-item design, and we used unrelated words instead of dominant-to-dominant and subordinate-to-subordinate priming pairs in the control conditions. These were necessary modifications from the designs used in earlier L1 studies to accommodate language learners' lexical knowledge. With our strict measures to control the words' orthographic form complexity, word frequency, and transparency in the stimuli, the design can adequately reveal potential asymmetries between dominant and subordinate morphemes.

Table 1. Word frequency and number of strokes of the stimuli.

Prime	Word Frequency of the Prime (Log-Transformed)	Stroke Number of the Prime
Dominant condition (e.g., 光明–光临)	3.06	15.47
Subordinate condition (e.g., 光临–光明)	3.09	14.79
Control condition 1 (e.g., 严格–补充)	3.15	16.1
Control condition 2 (e.g., 补充–严格)	3.15	15.5

During the experiment, each participant saw 19 pairs of words in the dominant condition and subordinate condition in total, 36 pairs of words in the control condition, and 44 pairs of fillers. As participants were asked to engage in a lexical decision task and all control and experimental items should lead to "Yes" responses for lexical decision, the fillers were included to balance participants' "Yes" and "No" responses, and the target of the filler was always a nonword (i.e., non-interpretable) constructed by combining two real characters (e.g., 语亲).

3.3. Procedures

Participants were individually tested on desktop computers in a quiet laboratory. E-prime software (version 2.0.10, Psychology Software Tools, Pittsburgh, PA, USA) was used to present the stimuli. For the L2 group, on each trial, a fixation signal (a black "+") was first presented in the middle of the screen for 500 ms followed by a prime word. The prime was presented for 500 ms and replaced by a backward mask (#####) for 20 ms. Following the backward mask, the target was presented in the center of the screen until participants made a lexical decision on whether the target was a real word or not. The prime, the target, and the mask were presented in 32-point Kaiti font. Participants experienced 8 practice trials before the main experiment.

The L1 participants experienced the same experimental procedure as the L2 group, except that the display duration of the prime for the L1 group was 50 ms. The difference between the prime exposure time for the L1 and L2 groups was intentional and informed by existing literature: For orthographic and morphological priming in Chinese L1 adults, numerous studies showed that a short SOA was sufficient to induce priming effect from shared orthographic forms, e.g., 57 ms in Zhou et al. (1999), 43 ms in Rastle et al. (2000), and 40 ms in Tsang and Chen (2013a, 2013b). The 500 ms SOA for L2 participants was determined based on existing studies and trial runs. Y. Liu et al. (2007b) argued that "the very short SOAs that produce orthographic effects in skilled native Chinese speakers will not necessarily produce interpretable priming effects in learners" (p. 473), and these authors reported 500 ms to be a reasonable SOA for Chinese L2 adults because it enabled orthographic priming among beginning-level learners and allowed semantic activation among more experienced learners. Previous Chinese L2 reading studies also suggested that L2 learners' naming speed of high-frequency Chinese characters typically exceeds 1000 ms (e.g., Lin & Collins, 2012). Thus, a 500 ms SOA for compound-word primes would not be excessively long for our L2 participants. To further verify the feasibility of the SOA, we invited three students from the same population where we recruited our participants to run pilot trials and confirmed that our L2 participants would not be able to identify the primes at 500 ms SOA.

4. Results

We analyzed the data using linear mixed-effects modeling (Baayen et al., 2008) with lexical decision accuracy and RTs as dependent variables. We had two planned pairwise comparisons. That is, we were interested in how the dominant condition and the subordinate condition each differs from the control condition. The models were implemented in the lme4 and lmerTest packages in R.

We report the L2 group's results first. Two participants were excluded from data analysis because of their lower accuracy (lower than 0.8). The 80% threshold conforms to the norms of practice in lexical decision tasks in word recognition research (e.g., Diependaele et al., 2012) and is also considered acceptable in other processing studies (C.-T. J. Liu & Chen, 2017). Trials with incorrect lexical decision responses and with reaction times that exceeded 2.5 SDs of each participant's average were excluded from the analysis of the lexical decision times. Table 2 illustrates the means and standard deviations in accuracy and reaction times in each condition.

Table 2. L2 participants' accuracy and reaction times (ms) of lexical decision (N = 18).

	Accuracy (*SD*)	**Reaction Times (*SD*)**	**95% CI of Reaction Times**
Dominant condition (i.e., prime–target: 光明–光临)	0.95 (0.22)	1019 (491)	[792, 1246]
Subordinate condition (i.e., prime–target: 光临–光明)	0.97 (0.17)	1079 (569)	[816, 1341]
Control condition (i.e., prime–target: 严格–补充)	0.97 (0.16)	1111 (555)	[848, 1373]

Logistic models were used to analyze the lexical decision accuracy because of the binominal distribution. In general, participants showed high accuracies in all three conditions. The best-fit model included the prime condition as a fixed effect and random intercepts for participants and items as random effects. Neither the dominant condition (estimate = −0.91, SE = 0.82, z = −1.11, p = 0.27) nor the subordinate condition (estimate = −0.16,

SE = 0.88, z = −0.19, p = 0.85) showed differences from the control condition in lexical decision accuracy.

In the measure of lexical decision times, the best-fit model included prime condition as the fixed effect and random intercepts for participants and items as random effects. The lexical decision times in the dominant condition were significantly shorter than the control condition: estimate = −100.01 ms, SE = 49.84, t = −2.007, p = 0.048. The lexical decision times in the subordinate condition did not show differences from the control condition: estimate = −27.12 ms, SE = 49.17, t = −0.552, p = 0.58.[3]

To analyze L1 participants' lexical decision accuracy and reaction times, we used the same procedures of modeling. Table 3 lists the means and standard deviations in accuracy and reaction times in each condition for the L1 group. Neither the dominant condition (estimate = −0.64, SE = 1.42, z = −0.45, p = 0.65) nor the subordinate condition (estimate = −0.64, SE = 1.42, z = −0.45, p = 0.65) showed differences from the control condition in the accuracy of lexical decisions. Trials with incorrect lexical decision responses, or with reaction times that exceeded 2.5 SDs of each participant's average, were excluded in the analysis of the lexical decision times. Neither the dominant condition (estimate = 9.34, SE = 39.20, t = 0.24, p = 0.81) nor the subordinate condition (estimate = −10.02, SE = 39.36, z = −0.26, p = 0.80) showed differences from the control condition.

Table 3. L1 participants' accuracy and reaction times (ms) of lexical decision (N = 23).

	Accuracy (*SD*)	**Reaction Times (*SD*)**	**95% CI of Reaction Times**
Dominant condition (i.e., prime–target: 光明–光临)	0.995 (0.07)	798 (323)	[648, 947]
Subordinate condition (i.e., prime–target: 光临–光明)	0.995 (0.07)	788 (385)	[610, 966]
Control condition (i.e., prime–target: 严格–补充)	0.998 (0.05)	795 (440)	[617, 973]

5. Discussion

5.1. Morphemic Processing Among L2 Readers

We started with discussions of the results in our L2 group. The above results showed that compounds with a dominant-meaning morpheme (i.e., dominant primes) facilitated the recognition of compounds with a subordinate-meaning morpheme (i.e., subordinate targets), but not the other way around. This facilitation effect was reflected in the shorter lexical decision times observed in the dominant condition, in comparison to the control condition. This finding led to several interpretations regarding L2 readers' processes in compound word recognition involving ambiguous morphemes.

First, the results validated that morphemic activation takes place in compound word reading involving ambiguous morphemes among L2 Chinese readers. The processing route of Chinese compounds involving ambiguous morphemes has been subject to debate in the L1 literature, and one argument for the whole-word processing was that the decomposed route via morphemic activation would be too costly, given the need to disambiguate the polysemous morphemes (e.g., Packard, 1999 vs. Wu et al., 2017). The topic has hardly been examined in the L2 context, despite the importance of polysemous morphemes in learning Chinese as a foreign language. As earlier research points out, orthographic-sharing at the word level typically either induces inhibition or no priming effect (e.g., Rastle et al., 2000). If our L2 participants had adopted a purely unitary route to recognize the compound words without the involvement of morpheme level information, we would not expect facilitation effect in either of our experimental conditions. This indicates that the

L2 learners in our study started to develop sublexical-level (i.e., morpheme- or character-level) representations, which is essential to developing high-quality word representation. As Chinese obligatorily marks morpheme boundaries, this feature likely leads to advantages in morphemic processing in word recognition. When a compound word is presented, learners can easily locate each morpheme and retrieve the sound and meaning constituents mapping to the form based on that perceptual unit. L2 learners may also have been facilitated by the salient visual boundaries in their establishment of sublexical representations.

The facilitation effect from the shared morphemic forms is consistent with the findings in L1 studies with short SOAs. For instance, Zhou et al. (1999) reported that compounds containing ambiguous morphemes facilitated each other both in masked priming and short SOA priming. Similarly, Rastle et al. (2000) found a facilitating priming effect between morphologically and orthographically related but semantically unrelated word pairs in English (e.g., apartment–APART) in their short SOA conditions. Such a facilitating effect is interpreted as evidence of morpho-orthographic activation since the advantage can only be attributed to shared morphological forms. Based on that, the facilitation effect in the current study reflects learners' morpho-orthographic processing when reading compounds.

The facilitation effect is not consistent with a morpho-semantic activation hypothesis. Semantic activation is believed to cause inhibition in ambiguous morpheme priming (i.e., longer lexical decision times or lower accuracy rates in the experimental conditions than the control condition) (Zhou et al., 1999; Badecker & Allen, 2002; Rastle & Davis, 2008). If our L2 participants had activated the dominant meanings when reading the prime (光 for 'light' in 光明), they would be hindered in the processing of the target word 光临 ('welcome') due to semantic competition between the two conflicting meanings of 光. As we found a facilitation (faster reaction time in the dominant condition, in comparison to the control condition) instead of an inhibition effect, the present results conform to a morphemic-form activation explanation: learners' recognition of 光临 was facilitated because the orthographic (i.e., form) representation, but not meaning representation, of 光 was preactivated during participants' exposure to the prime 光明.

5.2. Meaning Frequency and Orthographic Representation Quality

While we explained above that the facilitation effect is due to the shared forms of the ambiguous morpheme, we needed to account for the fact that the priming effect is unidirectional. That is, morpheme forms in association with the dominant meaning (e.g., 光 'light' in 光明) helped with learners' recognition of morphologically and orthographically related targets (e.g., 光临), but the morpheme form with the subordinate meaning (e.g., 光 'honor' in 光临) led to no facilitation in the recognition of dominant targets (e.g., 光明). A plausible explanation is that meaning frequency affects learners' orthographic representation when learners have limited language experience in the language. As a morpho-orthographic priming effect crucially hinges on readers' activation of the form information, the priming effect asymmetry reflects the differences in L2 learners' orthographic representation quality: although 光 in both words have the same graphemic form, meaning frequencies could have led to differences in learners' form representation quality of 光 ('light') in 光明 and 光 ('honor') in 光. That is, for foreign language learners, high meaning frequency can be associated with a more specified and precise orthographic representation. When the prime contains 光 in association with the meaning of 'light', specified orthographic representation of the form is activated, leading to a priming effect in the recognition of the subordinate target (e.g., 光临), much like the process of morpho-orthographic priming among L1 readers. But when the prime contains a key morpheme encoding the subordinate meaning, learners retrieve vague and imprecise form representation; such activation offers little help in their recognition of other orthographically related forms. That is, the meaning vari-

able impacts learners' mental form representation of the morpheme, and only high-quality morpho-orthographic representation (i.e., in the case of dominant primes) leads to a facilitating priming effect.

There are both theoretical foundations and empirical studies that support how meaning or semantic knowledge can affect form representation quality. Taft (2003) pointed out that the precision of morpheme representations correlates with the variety of semantically related contexts that it occurs in: morphemes that occur in a single context have indistinct representations and morphemes with consistent meanings across contexts have more precise representations. As morpheme productivity (i.e., the variety of compounding contexts that a morpheme occurs in) generally correlates with morpheme meaning frequency in Chinese (e.g., Yang & Fu, 2014), Taft's theory can indicate the impact of morpheme meaning frequencies on the morpheme's form, sound, and meaning representations. An implication is that learners are more likely to develop more robust representations of morphemes encoding dominant meanings than representations of morphemes encoding indistinct or less frequently used meanings. The pattern witnessed in this study conforms to the suggestion that meaning frequencies affect morpheme representation quality. This explanation is also consistent with the Lexical Quality hypothesis (Perfetti, 2007; Perfetti & Hart, 2002), in which different constituent representations are integrated and stable phonological or meaning knowledge contributes to the identification of printed words. Such an inter-related relationship between constituents can apply to the sublexical level too.

Empirically, studies on children's language learning confirmed that meaning training benefits the formation of high-quality orthographic representations in word learning. For instance, Álvarez-Cañizo et al. (2019) measured the outcome of Spanish children's orthographic representation of obscure words after training by a decrease of the length effect in a reading aloud task. The researchers found that semantic information in training offered additional benefits beyond the facilitation through phonology. Quellette and Fraser (2009) confirmed the contribution of semantics to orthographic learning in a visual recognition task: English-speaking children were better at identifying pseudowords learned with the provision of semantic information than pseudowords presented in isolation. Quellette (2010) further showed that semantic information contributed to children's performance in spelling, a measure that directly assesses orthographic representation quality. That is, the contribution of meaning to orthographic representation is consistently observed across different measures and in different languages and learning contexts (including real words and pseudowords). Our findings extended these research results on the role of meaning in adults' L2 learning.

A key argument in this research is that meaning affects form representation in language learning context. Unlike L1 adults, whose mental representation of words in their native language is generally of high quality, L2 readers' orthographic form representation can often be vague, imprecise, or of low quality. This is especially so when learners are learning a language with complex orthography. For foreign language learners whose morpheme representation quality is subject to variation due to meaning frequencies, the orthographic representation of a dominant morpheme is more robust than the representation of a subordinate morpheme. In this study, the shared-morpheme form activated high-quality orthographic representation in the dominant condition, facilitating the recognition of the subordinate target; in the subordinate condition, no priming effect was detected because the form representation pre-activated during prime exposure was of low quality, and it was not specified or precise enough to facilitate word recognition tasks involving the shared form. That is, L2 participants' patterns observed here—the asymmetrical priming effect—was a reflection of their morpho-orthographic representation quality. If this explanation is true, then we expect our L1 group's pattern to be different, since proficient L1

readers' orthographic form representation should be consistently stable and of high quality, regardless of the form's meaning associations. 光 in 光明 and 光 in 光临 are equally "easily recognizable" and easily activated for L1 adults. Below, we discuss our L1 data that confirmed this.

5.3. Discussions of the L1 Patterns

The important takeaway from our L1 data is that there was no asymmetry between the dominant and subordinate conditions in the L1 group. That is, for L1 readers, the meaning dominance of the morpheme did not appear to affect their word recognition. That is in line with our explanation above, because L1 adults, unlike language learners, have high-quality representations of the compound words and their constituent morphemes, regardless of the meaning frequencies. Note that in our study, in order to accommodate L2 learners' language proficiency and to use the same stimuli for both participant groups, we used high frequency words, and form representations associated with all meanings are highly stable and specified for L1 readers. The differences between the dominant and subordinate meanings were not consequential enough to affect L1 readers' form representations. This pattern, i.e., no asymmetry between the dominant and the subordinate conditions, supports our suggestion that the results observed in the L2 group were due to weaknesses in learners' morphemic representation quality.

Although this study did not aim to resolve controversies in L1 readers' word recognition involving ambiguous morphemes, we attempted below to offer some tentative explanations for the lack of difference between the experimental conditions and the control condition for the L1 group. The shared morphemic forms between the prime and target in the experimental conditions (both the dominant and the subordinate condition) appeared to offer no facilitation to word recognition. A reasonable explanation is that competitions at the semantic level have canceled out any benefit that could have been afforded by the shared forms. As mentioned earlier, priming facilitation due to shared orthographic representations is likely to manifest at shorter SOAs for L1 readers, and the (in)consistency of semantic relationships can play a crucial role at longer SOA (Rastle et al., 2000; Zhou et al., 1999). The transparency effect (i.e., constituents in an opaque compound word causing difficulties in word recognition) in long-lag priming paradigm is an example (Marslen-Wilson et al., 1994; Rueckl & Aicher, 2008). In ambiguous morpheme research, inhibition caused by inconsistent meanings reduced the facilitation offered by form sharing in some studies (Zhou et al., 1999) while it completely canceled out the facilitation (Tsang et al., 2014) or led to an overall inhibition effect in others (Badecker & Allen, 2002). The relative strengths of form facilitation versus inconsistent meaning inhibition depend on various factors, including meaning or form frequencies, the languages' orthographies, and the experimental procedures (masked, unmasked, vs. long-lag priming) (e.g., Tsang et al., 2014). As we have chosen high-frequency words and morphemes in our study and high-frequency words usually involve faster processing times (Brysbaert et al., 2018), morpho-semantic processing could be involved for our L1 group, even though we used a relatively short SOA (50 ms). That is, in the experimental conditions for the L1 group, the competition at the semantic level between 光明 and 光临could have counteracted any facilitation offered by morphemic-form sharing between the pairs.

5.4. Implications to Language Learning

The present findings suggest that meaning frequencies, independent of form frequencies and complexities, can affect L2 readers' character and word recognition. In Yang and Fu's (2014, p. 123) discussion of learner difficulties with character recognition in compounds, they pointed out that learners have the most difficulties not with characters with

the most complex forms (e.g., characters with the largest number of strokes) but characters with the median number of strokes. The findings of this study suggested that one factor beyond orthographic form complexity and word frequency can be the meanings encoded by the character. For polysemous characters, learners may recognize them when they encode dominant meanings in compounds but have difficulties when they encode subordinate meanings. Although there is not a comprehensive record of the type of polysemous morphemes that challenge learners, some scholars noted examples of 识词不识字 that involve morphemic meaning variations: For instance, advanced-level learners recognized 目标 'target' (where 标 encodes 'aim') but failed to recognize 标准 'standard' (where 标 encodes 'standard'), or they recognized 原则 'principle' (where 则 encodes 'regulations') but not 否则 'otherwise' (where 则encodes a logical relationship) (Wu, 2000). Multiple morphemic factors could have contributed to learners' difficulties in identifying a learned character in compounds. For instance, Xu and Chen (2022) pointed out that bound morphemes can be more difficult than free morphemes. The present findings indicated that morphemic meaning frequency may be an additional reason that impacts learners' sublexical representational quality. Given that most Chinese characters are polysemous and used in compounds instead of in isolation, pedagogical attention can be directed to characters' meaning variations in context, supporting learners to extract the morpheme meanings from compounds and establish stronger form, sound, and meaning links at the sublexical level through explicit instruction. Notably, this suggestion corresponds to the character–word dual functional model recently proposed by L. Chen et al. (2024a) and validated in L. Chen et al. (2024b); it also aligns with field experts' pedagogical recommendations that word-based instruction should be complemented with increased attention to (ambiguous) characters or morphemes (Xu & Chen, 2022; Yang & Fu, 2014; Zhao, 2012).

6. Conclusions and Limitations

By investigating word recognition involving morphemic ambiguities among Chinese L2 readers, we found that pre-exposure to a compound containing the dominant-meaning morpheme facilitated the recognition of a compound with the critical morpheme encoding its subordinate meaning. We suggested that the asymmetrical priming effect was due to variations in L2 learners' orthographic representation quality, which is affected by morpheme meaning frequencies.

The findings add new insights into research on form–meaning interactions for language learners. It is one of the first few studies that teased apart a meaning frequency from a form frequency effect by examining meaning ambiguities in the foreign language learning context. As morphemic ambiguities (e.g., *in-* in *inside* and *invalid*; *-er* in *teacher* and *taller*) exist in many languages such as English, Finnish, Dutch, and Spanish, examining the processes involved in Chinese ambiguous morphemes yields informative data in word reading research. The findings complement existing literature on the influence of phonology and meaning on form.

Some limitations of this study should be acknowledged. First, the current design was admittedly constrained by Chinese L2 participants' vocabulary knowledge. As there was a limited number of compound words from participants' textbooks that met the requirements, the design involved different targets in different conditions to enable comparisons with 38 key compound words. While care was taken to exclude the influence from confounding factors such as semantic transparency, word frequency, and form complexity, future studies can benefit from a design where different types of primes are used for the same target. Similarly, as materials in this study were intentionally selected to suit L2 readers, they may not reflect optimum material design to address L1 lexical processing inquiries. The absence of differences in condition comparisons in our L1 data may be per-

tinent to this issue and merits further exploration in the future. Second, support for the contribution of meaning to orthographic representation in this study came from the asymmetrical performance in learners' word recognition, which could be indirect evidence for causal relationships between meaning and orthographic representation. To investigate how meaning variables enhance orthographic learning, future studies can consider providing L2 learners with different training conditions and assessing learning outcomes through other measures such as spelling. Finally, the influence of learners' L1 was not addressed in this study. From a pedagogical point of view, some scholars pointed out that compared to L2 Chinese learners with a Korean or Japanese L1 background, the 识词不识字 ('knowing the word but not characters in the word') phenomena may be a more serious issue among English native speakers learning Chinese (Yang & Fu, 2014). To some extent, this could be because Korean and Japanese contain many words of Chinese origin, and learners from these backgrounds may have been exposed to the Chinese orthographic form (through Hanja or Kanji) prior to Chinese learning. Presumably, such exposure could facilitate their morphological decomposition when reading Chinese compounds. For future investigations, we can benefit from research investigating morphemic form–meaning relationships and sublexical representation among speakers of other languages such as English.

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Appendix A

Table A1. Experimental materials.

	Character	Word with Dominant Meaning	Word with Subordinate Meaning
1	下 ('down')	下面 ('under')	下载 ('download')
2	平 ('even')	平衡 ('balance')	平常 ('ordinarily')
3	分 ('divide')	分手 ('separate')	分钟 ('minutes')
4	温 ('warmth')	温暖 ('warm')	温柔 ('gentle')
5	服 ('clothing')	服装 ('clothes')	服务 ('to serve; service')
6	关 ('to close')	关闭 ('to close')	关系 ('relationship')
7	公 ('public')	公园 ('park')	公平 ('fair')
8	客 ('guest')	客人('guests')	客观 ('objective')
9	善 ('kindness')	善良 ('kind')	善于 ('good at')
10	计 ('to calculate')	计算 ('to calculate')	计划 ('plan')
11	光 ('light')	光明 ('bright')	光临 ('to welcome')
12	节 ('festival')	节日 ('festivals')	节省 ('to save')
13	运 ('fortune')	运气 ('luck')	运动 ('exercise')
14	报 ('newspaper')	报纸 ('newspaper')	报名 ('to register')

Table A1. *Cont.*

	Character	Word with Dominant Meaning	Word with Subordinate Meaning
15	失 ('to lose')	失业 ('lose.jobs')	失望 ('disappointed')
16	领 ('to lead')	领导 ('to lead; leader')	领带 ('tie')
17	精 ('spirit')	精神 ('spirit')	精彩 ('wonderful')
18	机 ('machine')	机器 ('machine')	机会 ('opportunity')
19	单 ('one; solo')	单独 ('alone')	单位 ('unit')

Notes

[1] The reduction in the length effect was used frequently in other studies to measure orthographic representation formation (See Álvarez-Cañizo et al., 2019). The rationale is that when learners formed word orthographic representations, they would take a lexical instead of a sublexical route when reading out loud, leading to reduced time differences between short and long stimuli.

[2] Different criteria were used for dominent meaning reporting frequencies in earlier studies. Dominent meanings in *balanced* ambiguous morphemes/words had reporting frequencies of 27.5–60% in Tsang and Chen (2013b) and 40–74% (target words) and 37–69% (control words) in Sereno (1995). These earlier studies discussed potential differences between *balanced* and *biased* ambiguous words, with the latter referring to words with one meaning overwhelmingly dominating all others. In the current study, our priority was to ensure that all words, characters, and meanings (including subordinate meanings) were accessible to L2 participants. Thus, the criteria for meaning dominence in general ambiguity (rather than biased ambiguous words/morphemes) were used.

[3] Given our focus on lexical processes among high-proficiency Chinese learners, we included participants who had passed the tests of HSK 5 and HSK 6. Following a reviewer's suggestion for considering L2 proficiency, we conducted an additional round of analysis, including HSK level (HSK 5 vs. HSK 6) as a covariate in the model. The results for our experimental variable remained consistent: the lexical decision times in the dominant condition were significantly shorter than the control condition (estimate = −100.63 ms, SE = 49.83, t = −2.02, p = 0.047), whereas no difference was found between the subordinate and control conditions (estimate = −26.77, SE = 49.15, t = −0.55, p = 0.59). No main effect of language proficiency was observed (estimate = −271.99 ms, SE = 153.96, t = −2.02, p = 0.09).

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