What Roles Do Constituents Play in the Identification of Chinese Compound Words? A Meta-Analytic Review

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Abstract

Because compound words comprised of two (or more) constituents make up the majority of Chinese vocabulary, understanding how they are processed and identified is critical for understanding the mechanisms that support the reading of Chinese. This meta-analytic review thus investigated whether Chinese compound words are processed and identified in a compositional versus holistic manner. Our meta-analysis includes 268 constituent effect sizes derived from 81 studies involving 5,911 participants. Overall, we found a statistically significant, albeit small, constituent effect (Hedges' g_{rm} = 0.22, 95% CI [0.18, 0.25]). The magnitude of this effect varied across study designs, being significantly larger when words were presented in isolation than within sentences, and in studies using preview methods rather than natural reading. Consistent with compositional processing, evidence from both behavioral and neurophysiological experiments also suggested that constituent effects occurred at the orthographic, phonological, and semantic processing levels. These findings highlight the significant role of constituents in Chinese compound-word identification, encompassing both form and semantics. Finally, although these discoveries have significant implications for existing and future models of Chinese reading, we should warn the readers that the averaged effect sizes should be interpreted with caution. The present study showed substantial heterogeneity, which calls for future studies to understand the underlying reasons for the variabilities across studies.

Public Significance Statement

This meta-analysis suggests that, in Chinese reading, individual constituents of compound words have a small but significant facilitative effect on their orthographic, phonological, and semantic processing across different word presentation methods and tasks. These findings are important for understanding how compound words are processed and identified in Chinese but also shed light on the universal mechanisms of compound-word processing across languages. These findings also suggest that the unique properties of a language's script influence the cognitive mechanisms that support word identification. In the future, the findings from this study may help improve the efficiency of Chinese language instruction.

Keywords: Chinese reading, compound words, lexical processing, meta-analysis, reading models

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The world is full of hierarchical structures, with the rules and forms of language being a prime example (Pinker, 2000). For example, one common hierarchical structure in language is the class of compound words. Compound words are morphologically complex words consisting of two or more free morphemes, such as *snow* and *ball* in the compound word *snowball*. Compound words are important components of human language as they provide greater efficiency in communication and more possibilities for the creation of new words, increasing the capacity for free expression and allowing languages to evolve (Libben, 2014). Compound words are particularly common in Chinese, being formed by combining two or more characters. For instance, the character 雪 (meaning *snow*) and 人 (meaning *man*) can be combined to form the compound word 雪人 (meaning *snowman*). Because of their important role in language, psycholinguists are interested in understanding how compound words are represented in memory and how they are processed when they are encountered in speech and during reading.

In the current article, we aim to examine compound-word processing during the reading of Chinese. Our decision to focus on compound-word processing during Chinese reading is motivated by two considerations. First, although Chinese is an important world language spoken by approximately 1.3 billion people, it has remained relatively understudied by reading researchers despite its marked differences from the alphabetic scripts that have been the focus of most research (for discussion of these issues, see Reichle & Yu, 2024). Second, although all writing systems allow readers to use the orthographic forms of words to access their pronunciations and meanings from memory, different writing systems also have unique features that may affect how compound words are processed (Libben & Jarema, 2006). For example, because Chinese language makes extensive use of compounding, it is ideally suited to address the questions of how compound words are represented and accessed.

Indeed, many studies have examined the processing of Chinese compound words. These studies mainly focused on how these individual constituents affect compound-word processing, with the presence of constituent effects supporting a *compositional* view in which the meanings of a word's constituents are used to construct the meaning of the word, and the absence of such effects supporting a *holistic* view in which the meaning of the word is directly accessed from memory (e.g., see Taft et al., 1994; C. Wang & Peng, 1999; Yan et al., 2006). Unfortunately, these studies have yielded mixed results that have prevented strong conclusions about compound word processing and whether they are identified in a compositional or holistic manner. This paper therefore provides a systematic review of the evidence for constituent effects in the reading of Chinese compound words using meta-analytic techniques. By doing this, we aim to provide a more comprehensive account of Chinese compound-word processing and thereby advance our understanding of word identification.

In the remainder of this article, we first review some basic facts about Chinese compound words. We then review the key findings related to constituent effects in Chinese compound-word processing and identify potential moderators of these effects. We then introduce several models of compound-word processing and discuss points of theoretical contrast among those models. Finally, we describe the method and results of two meta-analyses that were conducted to estimate the overall size of constituent effects and their potential moderators using both behavioral and neurophysiological evidence.

Chinese Compound Words

Compounding is the predominant method of word formation in Chinese, accounting for over 80% of vocabulary (Institute of Language Teaching and Research, 1986). In Chinese, compound words typically consist of two or more characters, which are the fundamental written units. Each character represents a syllable and many of them can serve as stand-alone words. Consequently, most characters also correspond to a morpheme, the smallest unit of meaning within a language, although a very small number of morphemes require two or more characters. Constituents thus refer to the orthographic subunits that comprise compound words and that can correspond to either characters or morphemes. Although for the purpose of facilitating exposition we use the more generic term “constituent” to refer to both, it is important to acknowledge that they can be distinguished.

Given the prevalence of compound words in Chinese reading, it is important to understand how they are processed and identified. In contrast to most other languages, the Chinese writing system has three distinctive characteristics that might favor compositional processing of compound words. First, the absence of spaces between words in Chinese text likely eliminates the use of low-level visual information to demarcate most word boundaries. This presumably makes it difficult to process compound words holistically because their constituent characters are not perceived as being grouped together. Second, although Chinese text lacks explicit word-boundary markers, there are small spaces between the characters that allow them to be perceived and processed as discrete units. Finally, as noted earlier, individual characters usually correspond to single syllables and morphemes in Chinese, which might make them the natural units of processing during reading. Therefore, due to the visual structure of the writing system and the morpho-syllabic structure of Chinese, one might reasonably predict that the processing of Chinese compound words should be compositional in nature.

However, three other characteristics of Chinese might encourage readers to process compound words in a holistic manner. First, compared to alphabetic languages, Chinese words are shorter and less variable in length, with two-character words being the most common, followed by three- and four-character words (Huang et al., 2024). This means that multiple-character words can usually be perceived from a single fixation. Second, individual characters often correspond to multiple morphemes having different meanings. Because of the prevalence of polysemous morphemes in Chinese and the resulting ambiguity, semantic composition may be difficult and highly inefficient (Packard, 1999; Zou et al., 2019). Third, whole-word meanings can be weakly related or completely unrelated to their constituent meanings, suggesting that constructing the meaning of a compound word from the meanings of its constituents would often cause errors. These additional three properties of Chinese compound words might therefore make them less amenable to compositional processing.

A priori consideration of the characteristics of Chinese and its writing system thus prevents strong intuitions about the processing of Chinese compound words and whether their identification is more consistent with the compositional or holistic views. The next section of this article will therefore review the experiments that have attempted to provide a better understanding of how Chinese compound words are actually processed and identified.

Compound-Word Processing Experiments

In the last three decades, many experiments have investigated compound-word processing during Chinese reading. Although these experiments have adopted markedly different methodologies, most have attempted to address how lexical properties of constituents affect compound-word processing. This is typically done by manipulating specific properties of the constituents (see Table 1 for the examples of these manipulations) to examine how they affect the online processing of compound words, with the presence or absence of constituent effects being respectively interpreted as consistent with compositional or holistic models. In the following sections, we review these compound-word processing experiments—experiments that have motivated the current meta-analysis. These experiments differ in their word-presentation methods and experimental tasks, as well as their manipulations. Consequently, our meta-analysis assessed all of these variables as potential moderators of the magnitude of the constituent effects (see the coding criteria listed in Table 2).

Word-Presentation Methods and Experimental Tasks

Previous studies have varied how compound words are displayed, with some studies presenting words in isolation, without sentence contexts, and others presenting words embedded in sentences. These two presentation methods are not independent of the experimental tasks because some tasks (e.g., lexical decision) require participants to respond to isolated words whereas others (e.g., natural reading) require participants to identify words in sentences. The latter task obviously affords parafoveal preview of the words and, in some instances, enhances their predictability due to the prior contexts, with both of these factors facilitating processing (for reviews, see Rayner, 1998). Another difference is the nature of their task demands, with participants making binary responses (using buttons) or rapidly pronouncing words presented in isolation but identifying and integrating the meanings of the words during natural reading. These differences are profound in that lexical decisions, naming, and semantic decisions are relatively unnatural and thus slow and prone to error, whereas reading is inherently complex but affords the use of sentence-level semantic and syntactic constraints (in a manner that is arguably not well understood) to facilitate word processing. With those important caveats in mind, differentiating word-presentation methods and experimental tasks are crucial for gaining a nuanced understanding of compound-word processing. Below, we review studies of compound-word processing using different presentation methods and tasks (see Table 2 for details). As will become evident, some of these studies provide evidence for constituent effects and thus support compositional processing, whereas others do not.

Words Presented in Isolation. When compound words are presented in isolation, they are either displayed one at a time (i.e., single-word presentation) to minimize any influence of other words, or in rapid succession with an influence of other words (e.g., priming paradigms). Among the tasks that present words in isolation, lexical decision is the most common. Taft and Forster (1975) pioneered the use of lexical decision to study the processing of both affixed words and compound words (Taft & Forster, 1976). In these experiments, individual letter strings were displayed in succession and participants were instructed to make rapid decisions about whether each was a word or non-word using button presses, with the properties of the compound-word constituents (e.g., their frequency) being manipulated across conditions. Subsequent experiments of Chinese compound-word processing used similar paradigms by manipulating the properties of their constituent characters, including their frequency (e.g., Wang & Peng, 1999; Xiong et al., 2023; Zhang & Peng, 1992), positional frequency (Cao et al., 2023), neighborhood size (e.g., Huang et al., 2006; Tsai et al., 2006; Xiong et al., 2021), and number of meanings (e.g., Huang et al., 2011; Huang & Lee, 2018). Other tasks that have been used with isolated words include concreteness judgments (e.g., Han et al., 2014), naming (e.g., Xiong et al., 2023) and the oddball paradigm (e.g., Tsang et al., 2022). All of these paradigms share the same underlying logic: If the manipulated constituent properties elicit differences in response time and/or accuracy between conditions (e.g., more rapid responses to high- vs. low-frequency characters), then the results are interpreted as evidence that the constituents played a role in compound-word processing.

Priming paradigms have also been used to examine constituent effects on compound-word processing. In these experiments, a *prime* word is displayed before a *target* word, with the prime-target relationship (e.g., degree of morpho-semantic relatedness) being manipulated and participants responding to (e.g., naming) the target. A “priming effect” is then evident if the responses to targets for certain types of prime-target pairs (e.g., semantically related) are faster or more accurate than responses to targets in a baseline condition (e.g., unrelated prime-target pairs). Most experiments of Chinese compound-word identification have manipulated the morpho-orthographic, morpho-phonological, or morpho-semantic relatedness (see Table 1 for more details and examples) in prime-target pairs to examine which type(s) of information become available during compound-word processing (Chen et al., 2006; Tsang et al., 2014; Tsang & Chen, 2013; Wu et al., 2017, 2020; Zhao et al., 2021; Zhou et al., 1999), although a few experiments have investigated the effects of morphological structure (Gao et al., 2021; Yang et al., 2022), semantic transparency (Wang & Peng, 1999; Wu & Li, 2008), or phonological properties (Tsang, 2021; Wong et al., 2014). The results of these priming experiments generally support the hypothesis that constituent representations are activated during compound-word processing (Tsang et al., 2014; Wu J. et al., 2020). These constituent effects have also been observed with *masked priming* (i.e., when the prime is rapidly replaced by a visual mask to preclude it from conscious awareness), suggesting that constituent effects are both automatic and rapid (Tsang, 2021; Zhao et al., 2021; Zhou et al., 1999).

Words Presented in Sentences. Another approach to studying compound words involves embedding them in sentences with the task of natural reading. Participants in these experiments typically read normally displayed sentences while an eye tracker records the time spent looking at (i.e., processing) the compound words. As per isolated-word presentation experiments, in natural reading, researchers manipulate the constituent properties of compound words to determine if the reading time for those words vary as a function of the manipulations (e.g., Yan et al., 2006). Previous experiments with natural reading have shown constituent effects when manipulating their number of strokes (e.g., Zhang, 2012), positional probability (e.g., Cao et al., 2023), character frequency (e.g., Yan et al., 2006), contextual diversity (e.g., Chen, 2017), neighborhood size (e.g., Tsai et al., 2006), and semantic transparency (e.g., Liu, 2017). However, some experiments have failed to find significant constituent effects during sentence reading when manipulating character frequency or the semantic plausibility of the first constituents (e.g., X. Li et al., 2014; Ma et al., 2015; Yang et al., 2012; Zhou & Li, 2021). For example, J. Yang et al. (2012) showed that the plausibility of whole words affected their reading times, but that the plausibility of their first constituents did not. This inconsistent pattern of results indicates that more research is necessary to understand the processing of compound words during reading.

The final approach to studying compound-word processing involves embedding them in sentences and using a gaze-contingent *boundary paradigm* to manipulate the preview of the compound words. In this paradigm, a preview word is displayed at the location of a target word prior to the participant moving their eyes past an invisible "boundary" located between the pre-target and target words. The relationship between the preview word and target word (e.g., their orthographic similarity) is typically manipulated, with the underlying logic being the same as in priming experiments: Any reduction in the fixation durations on the target words as a function of the experimental manipulation provides evidence that information was extracted from the preview and facilitated target word processing.

Experiments using the boundary paradigm to examine Chinese compound-word processing have found effects of morpho-orthographic, morpho-phonological, and morpho-semantic relatedness during sentence reading, with the reading time on the targets (i.e., the compound words) being reduced for related as compared to unrelated previews (e.g., Pan et al., 2016). However, one experiment failed to find a benefit of morpho-semantic preview (Shen et al., 2018), with this null finding being attributed to holistic compound-word processing and speculation that earlier evidence for morpho-semantic preview benefit being due to confounds. (Although this null result may have been due to the experiment having insufficient power to detect morpho-semantic effects.) Because these findings are contrary to those from most experiments involving compound words presented in isolation, constituent effects may differ systematically between these two presentation methods. We therefore assessed the effect of word-presentation methods in our meta-analysis.

Constituent Orthographic, Phonological, and Semantic Processing

Word processing is a complex activity that involves accessing orthographic, phonological, and semantic information from memory, as described by many word-identification models (e.g., Seidenberg & McClelland, 1989; J. Yang et al., 2006, 2013; for a review, see Reichle, 2021). For that reason, researchers interested in Chinese compound-word processing have used various experimental manipulations (see Table 1 for details) in their attempts to demonstrate the orthographic, phonological, and/or semantic processing of constituents. Some of these manipulations mainly target one processing level while others either target multiple levels or are unspecified[1].

To date, a handful of mega-studies have used multiple regression models to investigate how linguistic characteristics of characters and/or words might affect their processing (e.g., Liu et al., 2007; Tse et al., 2022; Tse & Yap, 2018). In these studies, the number of strokes per character was treated as an orthographic variable. Similarly, the homophone density of the characters and the number of pronunciations per character were treated as phonological variables. And finally, the semantic transparency of a character and the number of meanings per character were treated as semantic variables. However, because manipulations of other character properties (e.g., their frequency) might affect multiple levels of processing, these properties have not been assigned to any specific processing level[2]. That being said, it is

[1] Our classification of processing levels was based on the original articles and were agreed upon by the first and last authors.
[2] To give some sense of the inherent difficulty is specifying processing levels, Tse et al. (2022) treats both character and word frequency as orthographic factors, whereas Stevens and

relatively easy to specify the processing levels targeted by manipulations of morpho-orthography, morpho-phonology, and morpho-semantics in priming and preview studies because the processing level of morphemes can be determined by comparing different conditions.

Orthographic Processing. Manipulations thought to influence the orthographic processing of constituents include number of strokes (e.g., M. Zhang, 2012), and morpho-orthography in priming and preview paradigms (e.g., Tsang et al., 2014). Similarly, although a constituent's visual complexity, as measured using its number of strokes, did not affect the fixation durations on compound words during reading, it did affect their propensity to be skipped (M. Zhang, 2012). Finally, effects of morpho-orthography in priming and preview studies showed that, compared to an unrelated control condition, a consistent orthographic prime or preview allows a compound word to be identified more rapidly (e.g., Tsang et al., 2021; Zhou et al., 1999). In addition to this behavioral evidence, neurophysiological evidence from studies using *electroencephalograms* (EEG), a method used to measure the brain's electrical activity, shows that morpho-orthographic relatedness reduces the components associated with visual processing that are observed around 200 ms post-stimulus onset (e.g., L. Chen et al., 2017; Wu et al., 2017).

Phonological Processing. Manipulations thought to influence the phonological processing of constituents include their homophone density, number of pronunciations, and morpho-phonology in priming/preview studies. Because each Chinese syllable corresponds to an average of four characters (Perfetti et al., 2005), *homophone density* (i.e., each character's number of pronunciations, including the same tone; see Footnote 1) affects the naming times of individual characters, with characters having high homophone density being named more

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Plaut (2022, p. 1680) suggest that "whereas stem frequency could be a more orthographically-driven effect, stem family size may be related to semantic processing."

rapidly. But during natural reading, the fixation durations on compound words were unaffected by the homophone densities of their constituents (Yan et al., 2013). However, in an experiment that involved meaning judgments, responses were slow for compound words having multiple pronunciations than those containing characters having only one pronunciation (Tan & Perfetti, 1999). Finally, experiments manipulating morpho-phonology have shown inconsistent results. For example, one priming experiment found that words having orthographically different homophonic morphemes did not prime each other regardless of prime-target *stimulus onset asynchrony* (*SOA*, or the time between prime and target onset; X. L. Zhou et al., 1999). However, a masked priming experiment found evidence that morpho-phonology facilitated the resolution of ambiguity associated with processing heteronymic morphemes (Tsang, 2021). And in two experiments of reading using a boundary paradigm, phonological preview benefit was not observed for skilled readers or during silent reading but was observed for both children and oral reading (Pan et al., 2016; W. Zhou et al., 2018).

Semantic Processing. Manipulations thought to influence the semantic processing of constituents include their number of meanings (Huang et al., 2011; Huang & Lee, 2018), semantic plausibility (J. Yang et al., 2012) and transparency (Han et al., 2014; Lee et al., 2021; Y. Wu & Li, 2018), and morpho-semantics (Tsang & Chen, 2013; Zhao et al., 2021). Priming and preview experiments manipulating morpho-semantic relatedness have provided some evidence of early processing of constituent meaning during Chinese compound-word processing (e.g., Zhou & Marslen-Wilson, 2000; Tsang & Chen, 2013; Zhao et al., 2021), although this evidence has been inconclusive when manipulating the semantic relatedness of whole words (Shen et al., 2018). For example, the effects of constituent meaning were absent in an experiment that manipulated the semantic plausibility of the first constituent in relation to its preceding context (J. Yang et al., 2012).

Other Experimental Manipulations

Several experiments have manipulated variables whose effects are more difficult to attribute to orthographic, phonological, or semantic processing (see Table 1). These include experiments that involve morphological priming, including experiments showing that target processing is facilitated by primes that shared a morpheme (e.g., Jia et al., 2013; Tsang et al., 2014). Because such effects may involve the pre-activation of orthographic, phonological, and/or semantic information, effects of morphological priming may implicate the processing of constituents at all three levels.

Other manipulations that may involve multiple processing levels are also listed in Table 1. For example, experiments manipulating the neighborhood size or neighborhood frequency of constituents have found that neighborhood size tends to facilitate compound-word processing whereas neighborhood frequency tends to have an inhibitory effect (e.g., Andrews, 1997; Huang et al., 2006; M.-F. Li et al., 2015, 2017; Yao et al., 2022). Likewise, experiments manipulating character position probability (i.e., whether an initial character occurs in many or few compound words) have found that low-frequency compound words tend to be processed more rapidly if they contain a high- than low-probability character (e.g., Cao et al., 2023; Liang et al., 2022; Yen et al., 2012). Finally, both character frequency (Cui et al., 2021; Xiong et al., 2023; Yu et al., 2021) and morpheme type (i.e., whether a morpheme can be or is more likely to be a single-character word; Gao et al., 2021; H. Yang et al., 2022; Zang et al., 2016) have also been examined. However, because these and other constituent properties are often intercorrelated (e.g., character frequency is correlated with neighborhood size), the results of the aforementioned experiments have been inconclusive. For example, among the experiments that have manipulated the constituent frequency, a few have reported no effects (e.g., natural reading, Ma et al., 2015; lexical decision with low-frequency compounds, Peng et al., 1999: lexical decision with high-frequency compounds;

Xiong et al., 2023), whereas others have reported that the frequency of single constituents either facilitates (e.g., lexical decision, Tsang et al., 2018; naming, Xiong et al., 2023; natural reading, Yan et al., 2006) or inhibits (e.g., lexical decision with opaque compounds, Peng et al., 1999; natural reading, Yu et al., 2021; lexical decision, Zhang et al., 2024) compound-word processing. There are many potential reasons for these mixed results, including interactions with other variables, task-related differences, and the limited statistical power of an individual study. In our meta-analysis, possible effects of the aforementioned manipulations are synthesized to provide more reliable estimates due to increased statistical power, and to determine whether the effects are limited to specific tasks.

Whole-Word Frequency

The whole-word frequency of compound words has been shown to affect their processing across experimental paradigms (X. Li et al., 2022). A few experiments have also manipulated whole-word frequency to determine if it interacts with constituent manipulations (e.g., Xiong et al., 2023; Yan et al., 2006; Yu et al., 2021). Unfortunately, the results of these experiments are largely inconsistent. For example, several experiments have observed constituent frequency effects only during the processing of either low- (Cui et al., 2021; Huang et al., 2011; Xiong et al., 2021, 2023; Yan et al., 2006) or high-frequency (Peng et al., 1999) compound words, whereas other experiments have observed either no constituent effects (Ma et al., 2015) or significant constituent effects for both high- and low-frequency compound words (Tse & Yap, 2018; Xiong et al., 2023; Yu et al., 2021). Given these inconsistent findings, our meta-analysis is important because it provides a more comprehensive assessment of the relationship between whole-word and constituent frequency during compound-word processing.

Simplified vs. Traditional Characters

Experiments of Chinese compound-word processing also varied with respect to whether the stimuli were presented using traditional (e.g., as in Huang & Lee, 2018; Lee et al., 2021; Tsang, 2021) or simplified (e.g., Xiong et al., 2023; Yang et al., 2022; Yu et al., 2021) characters. As discussed by Reichle and Yu (2024), mainland China introduced reforms in the 1950s to simplify the Chinese writing system and thereby improve literacy. Since that reform, two types of Chinese characters—the simplified characters used in mainland China and the more complex traditional characters used in Taiwan, Hong Kong, and Macao—have co-existed. Although traditional characters are more complex (i.e., consist of more strokes on average) than simplified characters, they are mutually intelligible and (with some additional effort) can be readily read by any skilled Chinese reader. The meta-analysis reported in this article provides an opportunity to examine if compound-word processing differs in any meaningful way across the two types of characters.

Models of Chinese Reading

As reviewed by Reichle and Yu (2018), most models of Chinese reading have been designed to explain and/or simulate the perceptual and cognitive processes that support the skilled identification of words, rather than the higher-level processing of sentences or discourse. Two exceptions are models that describe how the systems that are responsible for identifying words are coordinated with vision, attention, and the oculomotor system to produce the patterns of eye movements that are observed during skilled reading (Li & Pollatsek, 2020; Liu et al., 2024). In this section, we will review these two classes of models separately, focusing our discussion on what these models suggest about the nature of compound word processing in Chinese reading.

Models of Word Identification

One early account of Chinese compound-word identification (Packard, 1999) claimed that the compositional processing of compound words would be highly inefficient due to the complex mappings between characters and morphemes, with more than 50% of characters corresponding to homographic morphemes having multiple meanings. For example, the character 教 means *teach* in 教室 (*classroom*) but means *religion* in 教堂 (*church*). And similarly, the spoken Chinese syllable “xin1” maps to multiple characters with different forms, meaning *heart* in 心痛 (xin1tong4, *heartache*) but meaning *bitter* in 辛苦 (xin1ku3, *hard work*)[3]. Given that homophones on the multi-character word level are much less common than homophones on the character level, Packard (1999) argued that the efficient resolution of such ambiguities necessitates the holistic processing of compound words.

More recently, several computational models have been proposed to simulate the identification of characters (e.g., Chang et al., 2016; Hsiao & Shillcock, 2004, 2005; Xing et al., 2002, 2004; J. Yang, 2013; J. Yang et al., 2006, 2009; for reviews, see Reichle & Yu, 2018, 2024), although only a few of these models have been explicitly designed for compound words (e.g., Smith et al., 2021; see Table 3 for details). These models have been implemented as (connectionist) neural networks (see Appendix C of Reichle, 2021) and for that reason are arguably more consistent with the holistic view of compound word processing. In these models, patterns of activated input nodes corresponding to the orthographic features of characters are used to generate patterns of activated output nodes corresponding to their pronunciations and/or meanings. For example, Smith et al. (2021) used the *Triangle model* (Plaut et al., 1996) to examine word identification across several writing systems, including Chinese. In one simulation, Smith et al. used the orthographic features of disyllabic words to activate semantic features representing their meanings; because this

[3] For those unfamiliar with Chinese, the number associated with the pronunciation indicates the tone of a character, with 1 indicating a flat tone, 2 indicating a rising tone, 3 indicating a tone that falls then rises, and 4 indicating a falling tone.

simulation did not require intermediate levels of representation corresponding to constituents, it instantiated holistic processing.

However, contrary to Smith et al. (2021), a number of models of compound-word identification (e.g., Perfetti et al., 2005; Taft et al., 1999; Taft & Zhu, 1997; Tan & Perfetti, 1999) have adapted the basic framework of the *interactive-activation* model (McClelland & Rumelhart, 1981) to Chinese and thus include intermediate levels of representation (e.g., characters). Although many of the specific assumptions of these models differ[4], the models collectively predict effects of constituent processing (e.g., facilitative character-frequency effects, or more efficient processing of compound words comprised of high- than low-frequency characters; see Yu et al., 2021.)

Some of the aforementioned models also assume that semantics play a role in compound-word processing. For example, according to the *inter/intra connection* (*IIC*) model (Peng et al., 1999), the meanings of both morphemes and words are represented, with positive connections between morphemes and semantically transparent words but negative connections between morphemes and opaque words. Similarly, according to the *lemma model* (Taft & Nguyen-Hoan, 2010), both morphemes and words are semantically represented, with transparent words being identified in a compositional manner but opaque words being identified in a holistic manner. And according to the model proposed by X. L. Zhou and Marslen-Wilson's (2000), the orthographic, phonological, and semantic forms of constituents are represented, but with only the meanings of compound words being represented. By this third account, the meanings of characters and words are activated in parallel, with the amount of semantic overlap among the representations fluctuating and often resulting in competition, allowing the model to explain morpho-semantic priming effects. Finally, Tan and Perfetti's

[4] The models also vary in terms of their degree of formal implementation, with some being complete models that can be used to run simulations (e.g., Tan & Perfetti, 1999) and others being diagrams meant to illustrate key theoretical assumptions (e.g., Taft et al., 1999).

(1999) model assumes independent orthographic and phonological representations for characters and words but shared semantic representations, allowing the model to simulate the complex patterns of priming observed with orthographic, phonological, and semantic priming (Perfetti et al., 2005).

Table 3 lists all of the aforementioned models, along with their core assumptions and the experimental tasks that they explain. Although our review of these models is by necessity brief, the key point is that these models make different predictions regarding the role of constituents during the identification of compound words, broadly consistent with our earlier holistic (e.g., Giraudo & Grainger, 2001) versus compositional (e.g., Taft & Forster, 1975, 1976) distinction.

Models of Eye-Movement Control

In addition to the above word-identification models that were designed to simulate the processing of characters and/or words presented in isolation, there have been two recent attempts (see Table 3) to explain word identification during natural reading[5]. The first was Li and Pollatsek's (2020) *Chinese Reading Model* (*CRM*), which combines a variant of the interactive-activation model (McClelland & Rumelhart, 1981) adapted to Chinese with assumptions that allow the model to simulate eye movements during reading. According to this model, compound words are identified via the propagation of visual input corresponding to their constituent characters through a network of character and word nodes, resulting in a "winner-take-all" competition in which the node representing the compound word suppresses the partially active nodes of any words sharing those constituents (e.g., orthographic neighbors). Although the CRM has not been used to explicitly simulate constituent effects, it has been used to examine how properties of whole words affect eye movements during

[5] Another model of Chinese reading was recently proposed by Fan and Reilly (2023). Because many of the implementational details of this model were not provided, it will not be discussed further.

reading, and from these simulations it is clear that the model predicts constituent effects at the *orthographic* level because of its assumption that all words (including single-character words) are activated and compete as previously described. Because the model does not implement semantics, however, it does not make a clear prediction about meaning-based constituent effects.

The second model that explains word identification in natural reading is the *Chinese E-Z Reader* model (*CEZR*; Liu et al., 2024; see also Yu et al., 2021). This model extends the E-Z Reader model of eye-movement control in (English) reading (Reichle et al., 2012) by incorporating a familiarity-based word-segmentation heuristic in which groups of characters are segmented into words for the purpose of their identification. This model has been used to simulate the complex effects of character frequency on eye movements. For example, it captures both facilitative effects of character frequency and an inhibitory initial-character frequency effect reported by Yu and colleagues. This complex pattern reflects the fact that, on one hand, character frequency enhances a word's familiarity, making it easier to segment and identify, but on the other hand, high-frequency characters tend to be the constituents of many words, making the segmentation of those words more difficult. Because the CEZR does not implement semantics, it also makes no clear prediction about meaning-based constituent effects.

Taken together, it is important to acknowledge that all of the aforementioned models make nuanced predictions about constituent processing—whether it is necessary for identifying compound words and, if so, whether it occurs at the orthographic, phonological, and/or semantic level(s) (see Table 3). Examining the evidence that might be used to evaluate these predictions is therefore critical for distinguishing among and evaluating the models. This is obviously only possible when the constituent effects and their potential moderating variables are well understood. Below, we provide an overview of the meta-analytic method that we used to examine the effects of compound-word constituents in Chinese reading.

The Present Study

Using meta-analytic techniques, this article sought to synthetize findings from existing experiments that have examined constituent effects in the reading of Chinese compound words. This meta-analysis was designed with three main goals in mind: (1) to estimate the size of constituent effects and identify possible sources of inconsistency by assessing potential moderating variables (e.g., whether the word was presented in isolation or in sentences); (2) to evaluate the constituent effects as a function of orthographic, phonological, and semantic processing; (3) to investigate the roles of various constituent properties across tasks. In accomplishing these goals, our intention is to also address the hypotheses that were outlined in the previous section—hypotheses that were motivated by and inform models of Chinese reading. However, it is also important to be clear about the advantages of our meta-analytic approach.

Although there are comprehensive literature reviews and entire books about compound-word processing, most focus on alphabetic languages (e.g., Libben, 2014; Libben & Jarema, 2006; Semenza & Luzzatti, 2014). To our knowledge, no systematic meta-analytic investigation on Chinese compound word processing has been conducted, therefore suggesting that such a meta-analysis of Chinese experiments is necessary. Whereas standard literature reviews only provide qualitative summaries, meta-analyses allow one to systematically search the literature and select the eligible experiments to include in the analysis, thereby reducing the risk of bias and providing a numeric estimate of overall effect sizes (Shamseer et al., 2015). Moreover, compared to individual experiments, meta-analyses have more statistical power to detect effects that may be small in magnitude and thus unreliable in individual experiments. Thus, meta-analyses can generalize findings across various contexts and methodologies, thereby providing a more comprehensive understanding of Chinese compound-word processing as well as the potential reasons for variability across individual experiments.

Hypotheses

According to holistic processing accounts (e.g. Packard, 1999; Smith et al., 2021), constituents will not affect compound-word processing, and therefore, the overall constituent effect is assumed to be absent. In contrast, models that assume either simple compositional processing (e.g., Peng et al., 1999; Taft & Nguyen-Hoan, 2010) or some form of competition between representations of constituents and words (e.g., Li & Pollatsek, 2020; Yu et al., 2021) would presumably predict the presence of constituent effects.

Regarding the potential moderators examined in the current study, there were no a priori predictions for task, manipulation, writing system, presentation paradigm, publication year, or publication type. However, with respect to presentation method, both the CRM (X. Li & Pollatsek, 2020) and CEZR (Yu et al., 2021) models posit that sentence context influences the activation of constituent and whole-word representations, predicting weaker constituent effects when compound words are processed in sentences. In contrast, holistic models predict no difference between isolated and sentence-based presentation, as compound words are processed as unified wholes regardless of their context. In addition, holistic and compositional models make different predictions about the presence of constituent effects at the orthographic, phonological, and semantic levels: Holistic models assume that these effects should not be significant (Packard, 1999; Smith et al., 2021), whereas compositional models assume that they should (Peng et al., 1999; Taft & Nguyen-Hoan, 2010). Finally, whole-word frequency[6] is predicted by models that assume there is stronger interactive

[6] The moderator analyses on whole-word frequency are reported in Appendix B.

activation among the representations of whole-word and their constituents, which results in stronger constituent effect in processing high-frequency compound words (e.g., Peng et al., 1999).

Method

Selection of Studies

Search Strategy

In June 2022, we systematically searched four electronic databases (Web of Science, PubMed, PsycINFO, and Scopus) to identify research articles published in English, as well as CNKI[7] for articles published in Chinese, using search terms "compound words + Chinese read*", "two-character words + Chinese read*", and "complex words + Chinese read*" (where the asterisks are wildcards that allowed the inclusion of "read", "reading", "reader", etc.). To capture research that was not published in peer reviewed journals, we also searched ProQuest Dissertations & Theses Global, and CNKI (dissertation). Overall, we identified 1,335 articles from these searches. Additionally, we conducted systematic backward and forward citation searches to identify 20 additional articles. And in January 2024, another 18 newly published or previously missed articles were added. After removing duplicates, there were 958 unique articles. The titles and abstracts of these articles were screened by the lead author who made decisions to either exclude the study or review the full article. This screening resulted in the exclusion of 837 articles, leaving 121 articles to be further assessed for eligibility. The lead author then downloaded and read these articles. Based on our exclusion criteria, 81 articles were included in the meta-analysis, allowing 268 effect sizes to be extracted (see Figure 1 for a flowchart of literature search). Table A1 provides a list of all included studies.

[7] *CNKI* (*China National Knowledge Infrastructure*) is a comprehensive digital library and knowledge database platform in China that provides access to academic journals, dissertations, conference proceedings, and other scholarly resources.

Inclusion and Exclusion Criteria

Full-text articles were assessed for eligibility based on the following criteria:

(1) Articles were written in either English or Chinese.

(2) Articles reporting experiments with factorial designs. Corpus analyses were excluded because they use different methods to estimate effect sizes. Studies that simply re-analyzed data from other articles were excluded. Furthermore, if the same data were reported in both a dissertation and a published article, only the latter was included. And if the same materials were used in multiple experiments using different participants or tasks, then the experiments were included and treated as different studies.

(3) Experiments involving participants who were non-clinical adults, native speakers of Chinese, and skilled readers. We excluded the data collected from clinical samples, children, and elderly participants because our aim was to examine compound-word processing in skilled adult readers rather than focusing on individual differences or developmental changes. We only included studies of native speakers to reduce the effects of experience with other languages.

(4) Experiments in which two-character Chinese compound words were used as the target stimuli[8] and character properties were manipulated to assess their effects on compound-word identification. Because our primary interest is visual word identification, we only included experiments in which the compound words were displayed on a screen and excluded experiments involving either their auditory or pictorial equivalents. Experiments in which the text was presented one character at a time were also excluded, as were experiments that measured the learning of novel compound words, the identification of non-words

[8] We also extracted three effect sizes from one experiment using a primed lexical decision task (Tan & Peng, 1991). Although the target words in this study were single characters, the prime words were two-character compound words. The experiment was thus included in our meta-analysis because the response times for the target characters differed between conditions, suggesting access to the constituents of the compound-word primes.

comprised of transposed characters, or requiring any type of secondary task. Experiments manipulating only the characteristics of the whole-word level were also excluded.

(5) Experiments that measured response time for tasks requiring overt responses or experiments that reported *gaze duration*, where the latter measure is defined as the sum of all first-pass fixations on a word. Eye-tracking experiments that did not report gaze durations were excluded because the measure provides the most commonly used index of lexical processing (e.g., Rayner, 1998).

(6) Articles in which the information required for calculating effect sizes was reported. Articles that did not report this information (e.g., studies reporting means without standard deviations) were excluded.

Data Coding Procedures

For each eligible study, the lead author extracted all information required to calculate effect sizes (i.e., sample sizes, means and standard deviation, *t*- or *F*-values) and the variables to be assessed as potential moderators (see Table 2 for more details about the coding criteria). For those studies that did not report standard deviations or specific statistical values, we emailed the corresponding authors to ask for the necessary data. Additionally, ten articles provided raw data so that the Pearson's correlations in Equations 1–3 for within-subject designs could be calculated. A description of each study included in the meta-analysis is provided in Table A1.

Coding of Effect Sizes

Following the recommendation of Lakens (2013), we used Cohen's d (i.e., standardized mean difference) for repeated measures and used Hedges' g corrections as our effect size index (hereafter referred to as g_{rm}). We first calculated Cohen's d for repeated measures, d_{rm}, using the means and standard deviations, t-values, or F-values with Equations 1–3, respectively.

$$d_{\mathrm{rm}} = \frac{M_1 - M_2}{\sqrt{SD_1^2 + SD_2^2 - 2correlation \times SD_1 \times SD_2}} \sqrt{2(1 - correlation)} \quad (1)$$

$$d_{\mathrm{rm}} = t\sqrt{\frac{2(1 - correlation)}{n}} \quad (2)$$

$$d_{\mathrm{rm}} = \sqrt{\frac{2F(1 - correlation)}{n}} \quad (3)$$

We then applied Hedges's *g* corrections to get g_{rm} and the corresponding estimated sampling variance in *R* 3.4.0 (R Core Team, 2017) using Equations 4 and 5.

$$g_{\mathrm{rm}} = d_{\mathrm{rm}}\left(1 - \frac{3}{4(n-1)-1}\right) \quad (4)$$

$$\text{sampling variance } g_{\mathrm{rm}} = \left(\left(1 - \frac{3}{4df-1}\right)\sqrt{\left(\frac{1}{n} + \frac{d_{\mathrm{rm}}^2}{2n}\right)\left(2(1 - correlation)\right)}\right)^2 \quad (5)$$

Table 1 provides the definition and examples for each manipulation included in the meta-analysis. M_1 and SD_1 in Equation 1 correspond to the means and standard deviations in the control conditions, whereas M_2 and SD_2 correspond to the same statistics in the experimental conditions. Effect-size calculations adhered to the methodology described by Borenstein (2009), allowing estimated effect sizes for different manipulations to be interpretated similarly. The control and experimental conditions for most of the manipulated variables were defined in reference to the results of empirical studies of single-character processing, with the condition in which the character was processed more rapidly being defined as the experimental condition (e.g., C. Lee et al., 2015; Liu et al., 2007; Sze et al., 2014). Variables related to priming or preview paradigms (i.e., studies that manipulated morpho-orthographic, morpho-phonological, morpho-semantic, and morphological relatedness) were coded using the same criteria as the experimental condition, affording consistency between primes and targets. Thus, for those manipulations, positive effect sizes indicate facilitative constituent effects on compound-word identification, with faster processing of constituents (e.g., high-frequency constituents) resulting in faster compound-word processing (i.e., shorter response time or gaze duration). Conversely, negative effect sizes indicated inhibitory constituent effects. Because the variables of semantic transparency and position probability were not included in studies of single-character identification, it was not possible to quantify the processing speed or difficulty of the constituents at the different levels of those two variables. Consequently, these variables were coded separately (as defined in Table 2), and their effect sizes should be interpreted with caution. For example, positive effect sizes indicate that compound words containing transparent constituents or constituents having a high position probability were processed more rapidly.

For within-subject designs, a correlation between the two conditions (*correlation* in Equations 1–3) being compared is necessary for calculating effect sizes (Lakens, 2013). However, those correlations were only available for 28 effect sizes[9]. We therefore applied a mean imputation method to estimate missing correlations using the available data. Because one sample might contain more than one effect size, we first aggregated the dependent correlations through conducting a meta-analysis on the aggregated estimates, and then used this meta-analytic correlation estimate for imputation. The estimate revealed by the meta-analysis for the correlation coefficient was r = .71, 95% CI [.63, .78], based on 17 individual samples of 659 participants. All effect sizes are reported in Table A1. We conducted

[9] Among the 28 effect sizes, 15 were extracted from studies on natural sentence reading (average correlation = 0.66), 5 on lexical decision (average correlation = 0.86), 3 on reading with boundary paradigm (average correlation = 0.78), 3 on primed lexical decision (average correlation = 0.77), 2 on naming (average correlation = 0.87). The average correlation between within-subject conditions did not vary much across tasks.

sensitivity analyses to examine how the pooled estimate changed when the correlation was set higher (r = .90) or lower (r = .50).

Coding of Study Characteristics/Methodological Moderators

The coding criteria were discussed by two authors (see the Table S1 coding book in Supplementary Materials 1 and Table 2 for more details). The lead author then coded the study variables, with some being assessed as potential moderators. For each study, we extracted the following information:

(1) *Word-presentation method* was coded into two categories: (i) words displayed in isolation (i.e., without sentences) versus (ii) words displayed in sentences.

(2) *Paradigm* was coded into four categories: (i) single-word; (ii) priming; (iii) natural sentence reading; and (iv) reading using a preview (i.e., boundary) paradigm. Paradigms were limited to word-presentation method, which means compound words in the first two paradigms were presented in isolation (i.e., coded as *IsolateParadigm* in analysis) while those in the latter two were presented in sentences (i.e., coded as *SentenceParadigm* in analysis).

(3) *Experimental task* was coded within the two word-presentation methods and included: (i) lexical decision; (ii) naming; (iii) semantic decision; (iv) primed lexical decision; (v) primed naming; (vi) primed semantic decision; (vii) natural reading; and (viii) reading using a preview (i.e., boundary) paradigm. Experimental tasks were limited to the specific paradigm of the study: (i), (ii), and (iii) were used in single-word paradigm; (iv), (v), and (vi) were used in priming paradigm; (vii) was used in natural sentence reading paradigm; and (viii) was used in reading using a preview paradigm.

(4) *Manipulation* was coded based on the independent variable used in each study. There were 16 different manipulations across all eligible studies: (i) morpho-orthography (in priming/preview studies); (ii) position probability; (iii) number of strokes; (iv) homophone density; (v) morpho-phonology (in priming/preview studies); (vi) number of pronunciations;

(vii) morpho-semantics (in priming/preview studies); (viii) number of meanings; (ix) semantic plausibility; (x) semantic transparency; (xi) morphological priming; (xii) character frequency; (xiii) contextual diversity; (xiv) neighborhood size; (xv) morphemic relation priming; and (xvi) morpheme type.

(5) *Processing level* was coded into three levels: (i) orthographic; (ii) phonological; and (iii) semantic. Experiments in which the manipulation could not be unambiguously assigned to one of these three levels were excluded in our analysis of processing level.

(6) *Compound-word frequency* was coded into (i) high- versus (ii) low-frequency when the authors of the original studies explicitly reported the stimuli as such in their articles. The sources used to tabulate word frequency were recorded if they were reported.

(7) *Writing system* was coded as (i) simplified versus (ii) traditional Chinese.

(8) *Stimulus onset asynchrony* (*SOA*)[10] was coded as a continuous variable (in milliseconds).

(9) Other study characteristics: Publication year, sample size, and set size were coded as continuous variables, and publication type (journal vs. other sources) and publication language (Chinese vs. English) were coded as categorical variables.

Statistical Approaches

Fifty-eight percent of studies provided more than one effect size of interest. For example, Yu et al. (2021) examined character-frequency effects with high- and low-frequency compound words, so both estimates of the character-frequency effects were included to examine if compound-word frequency was a moderator. Multiple sources of dependencies often coexist, including the dependency from studies containing multiple effect sizes of interest and authors reporting multiple eligible studies. Therefore, we used three-

[10] Only a subset of studies using priming presentation contained the variable of SOA, and therefore, the results were reported in Appendix B for easier reading.

level random-effects meta-analyses to account for the variation attributable to participants (Level 1: sampling variance), sets of effects sharing a common sample (Level 2: within-sample variance), and pooled sample effects (Level 3: between-sample variance) with the restricted maximum-likelihood estimation method (Assink & Wibbelink, 2016; Harrer et al., 2022).

The overall effect size was estimated with a random-effects meta-regression model using package *metafor* (Viechtbauer, 2010) in R 3.4.0. The intercept of the model that was fitted from all of the available effect sizes indicated both the magnitude and direction of the overall effect size. Within-sample and between-sample heterogeneities were assessed using log-likelihood ratio tests (*LRT*s). To assess moderating effects, we constructed separate meta-regression models on each level of each potential moderator to calculate corresponding overall effect sizes. If a level of a moderator did not contain sufficient observations (i.e., ≥ four effect sizes, as was true for three studies), then the effect sizes for this level were excluded. We examined each potential moderator in turn by including it as a predictor in a meta-regression. Continuous moderators were standardized before being entered as continuous variables in their respective models. Categorical moderator variables were dummy coded, with one level as the reference. The estimate of the intercept in the models thus reflect the overall effect size of the reference category, and therefore, the significance test for the coefficients indicated whether the differences were significantly different from zero.

Transparency and Openness

This review was not pre-registered. We followed PRISMA reporting guidelines for the final report. The data and analysis scripts are available online on the Open Science Framework (https://osf.io/ywg54/?view_only=68c0aea1c4924bad88fe5bb22b32a0af). To give a clearer picture of their findings about constituent effects, a table summarizing the conclusions of the studies included in the meta-analysis is available on the Open Science Framework (https://osf.io/ywg54/?view_only=68c0aea1c4924bad88fe5bb22b32a0af).

Results

We extracted 268 effect sizes from 81 articles consisting of 139 experiments (total N = 5,911 participants). The publication years of the articles identified ranged from 1991 to 2024 (M = 2014, Median = 2017). All experiments used within-subject designs and university students as participants with sample sizes ranging from 13 to 318. All samples consisted of native Chinese speakers, including samples from studies conducted in English-speaking countries (e.g., USA and UK). Overall, 55 (68%) articles were written in English, and 26 (32%) were in Chinese; 66 (82%) articles were peer-reviewed and published in journals, and 15 (18%) were other types of articles (e.g., theses, dissertations, and book chapters). Among all effect sizes, 186 were from experiments using simplified Chinese and 82 from experiments using traditional Chinese. A total of 185 effects were extracted from experiments on compound words presented in isolation, with 136 effects from priming experiments and 49 from single-word presentation experiments. Additionally, 83 effects were extracted from experiments where compound words were presented in sentences. In terms of compound-word frequency, experiments of low-frequency word processing yielded 28 effects, while experiments of high-frequency word processing yielded 27 effects. Experiments reporting the remaining effect sizes did not specify compound-word frequency. Detailed descriptive statistics of the numbers of effect sizes, the experiments, and the moderators for each task are summarized in Table 4.

Constituent Effects During Chinese Compound Word Processing

Overall Constituent Effect

We fit a three-level random-effects model of all effects to estimate the direction, magnitude, and significance of the overall constituent effect. The overall effect size was g_{rm} =

0.22, 95% CI [0.18, 0.25], $t(267) = 12.51$, $p < .001$, 90% prediction interval [−0.20, 0.63] (see Supplemental Figure S5 for the forest plot). This indicates that constituent manipulations have a small but significant effect on whole compound-word processing (Cohen, 1988). The overall effect was positive, indicating that, if the constituent of a compound word was processed rapidly, or was semantically transparent, or had a higher position probability, then the whole compound word was also processed more rapidly. There was substantial heterogeneity in the effect sizes, $Q_E(267) = 1444.17$, $p < .001$. An LRT revealed significant within-sample variance, σ^2(Level 2) = .063, $\chi^2(1) = 343.82$, $p < .001$, indicating a heterogeneous effect size distribution. However, the between-sample variance was not significant, σ^2(Level 3) < .001, $\chi^2(1) < .001$, $p > .999$.

The heterogeneity diagnostics based on Baujat plot identified three effect sizes that contributed substantially to the overall heterogeneity (see Figure 2). However, the overall effect size did not change much after excluding these three effect sizes ($g_{\text{rm}} = 0.21$, 95% CI [0.18, 0.25]), and the heterogeneity remained substantial, $Q_E(264) = 1434.21$, $p < .001$. To further assess potential outliers, we calculated standardized residuals, considering values beyond ±2.24 as extreme (Aguinis et al., 2013; McKay et al., 2021). Because no such outliers were detected, subsequent analyses were performed using the complete dataset.

We further conducted sensitivity analyses to assess the robustness of our effect size estimate under alternative assumptions about the correlation between the two conditions in within-subject designs. Assuming a correlation of .50 yielded an overall effect size of $g_{\text{rm}} = 0.23$, 95% CI [0.19, 0.27], $t(267) = 11.60$, $p < .001$, 90% prediction interval [−0.24, 0.71]. Assuming a correlation of .90 yielded an overall effect size of $g_{\text{rm}} = 0.17$, 95% CI [0.14, 0.20], $t(267) = 12.03$, $p < .001$, 90% prediction interval [−0.19, 0.52]. These results indicated that the overall effect size remained small but statistically reliable despite slight fluctuations in correlations.

Publication Bias Analyses

It is possible that studies that have failed to find significant constituent effects were not published in journals (i.e., publication bias). To examine this possibility, we first examined the moderating effects of publication type and then used multiple methods to further evaluate potential publication bias in our meta-analysis.

Publication Type. In this meta-analysis, 45 effect size estimates were included from sources other than journals (i.e., theses, dissertations, and book chapters). When publication type was examined as a potential moderator, we found no significant difference between the magnitude of effect sizes from journal articles versus other sources, F (1, 266) = 0.13, p = .722.

Funnel Plot. A funnel plot was constructed with the x-axis representing aggregated within-sample effect size estimates and the y-axis showing the standard errors associated with each study (see Figure 3). The aggregated effect sizes were calculated using *agg* function in package *MAd*. If the distribution of effect size estimates resembles a symmetric inverted funnel (i.e., effect size estimates are distributed symmetrically around the line indicating the mean effect size, with those having larger standard errors being near the bottom and those with smaller standard errors being near the top), then it suggests the absence of publication bias. The overall distribution of the aggregated effect sizes and the results of Egger's regression test revealed significant asymmetry, $b = 2.37$, $t(266) = 4.88$, $p < .001$, indicating potential publication bias. It should also be kept in mind that high heterogeneity of the included effect sizes can also lead to asymmetry in the funnel plot.

Trim-and-Fill Technique. We used the trim-and-fill technique considering the dependency among effect sizes (Duval & Tweedie, 2000; Fernández-Castilla et al., 2021) to estimate the number of effect sizes that may have been suppressed due to selection bias. No missing effect sizes were imputed in our dataset, indicating no evidence of publication bias.

P-Curve Analysis. This analysis examines the distribution of statistically significant *p*-values ($p < .05$) to assess whether a body of research contains evidential values or is influenced by selective reporting practices (Simonsohn et al., 2014). A right-skewed *p*-curve suggests genuine effects, while a flat or left-skewed curve may indicate bias or null effects. Using a continuous *p*-curve analysis, the results showed that the statistically significant results (i.e., 122 of 268 effect sizes) were not likely to be driven by the selective reporting (see Supplemental Figure S4).

Summary. Different conclusions can be drawn from different methods to evaluate potential publication bias. Specifically, the funnel plot showed modest asymmetry in the distribution of effect sizes. However, neither the trim-and-fill technique nor the *p*-curve analysis detected overall publication bias. Notably, the high heterogeneity in the observed effect sizes makes interpreting such statistics more difficult, particularly because the trim-and-fill technique and the *p*-curve analysis tend to overestimate the average population effect size under high heterogeneity (Harrer et al., 2021; van Aert et al., 2016). Therefore, we cannot rule out the possibility of publication bias in studies of constituent effects.

Moderators for Constituent Effects

Because of the substantial heterogeneity in the effect sizes ($I^2 = 84.33\%$), we further conducted moderator analyses to examine possible differences among studies. Table 5 shows the pooled effect size (g_{rm}) calculated separately for each level of each moderator and the results of the moderator analyses. We assessed whether different presentations and the specific tasks included under each presentation method produced different constituent effects. Other potential moderators included compound-word frequency with categorical (high vs. low) coding, the writing system of the characters (traditional vs. simplified Chinese), and publication year.

Word-Presentation Methods and Experimental Tasks

Word-Presentation Methods. In studies investigating compound-word processing, the target words were presented either in isolation or in sentences. The constituent effect was significant in both presentation methods (in isolation: g_{rm} = 0.25, 95% CI [0.21, 0.29], $p < .001$; in sentences: g_{rm} = 0.13, 95% CI [0.07, 0.19], $p < .001$); however, the effect size was significantly smaller when processing compound words embedded in sentences than in isolation, $F(1, 266) = 11.31$, $p < .001$. Significant unexplained variance remained between all effect sizes after accounting for word-presentation methods, $Q_E(266) = 1350.15$, $p < .001$. The moderation effect of word presentation method was still significant after controlling for the effect of publication year, $t(265) = -2.70$, $p = .007$.

Compound words presented in isolation included the paradigms involving single-word presentation as well as priming experiments, with the former showing a small constituent effect (g_{rm} = 0.20, 95% CI [0.12, 0.28], $p < .001$) and the latter showing a small-to-medium effect (g_{rm} = 0.28, 95% CI [0.23, 0.33], $p < .001$). However, the difference in effect sizes between the two types of paradigms was not significant ($p = .114$). For compound words presented in sentences, the paradigm included natural reading and reading using a preview (i.e., boundary) paradigm. Subgroup analyses suggested a significantly larger constituent effect when reading with a preview paradigm (g_{rm} = 0.23, 95% CI [0.12, 0.33], $p < .001$) than natural reading (g_{rm} = 0.10, 95% CI [0.04, 0.16], $p = .001$), $F(1, 81) = 4.44$, $p = .038$.

Experimental Tasks. Because different tasks might require different stages of lexical processing, it was necessary to examine different tasks that were used within each presentation paradigm[11]. For tasks involving the presentation of single words, semantic

[11] Because natural reading or reading with a boundary only entailed one type of task (i.e., reading), task was not treated as a moderator for those two presentation paradigms. Although the priming paradigm involved three different tasks, only the primed lexical decision task yielded more than four effect sizes; thus, no further task-specific analysis was conducted.

decision was excluded due to an insufficient number of effect sizes (fewer than four). Lexical decision showed a small constituent effect (g_{rm} = 0.17, 95% CI [0.05, 0.29], p = .006), while naming showed a medium effect (g_{rm} = 0.45, 95% CI [0.15, 0.76], p = .004). The effect size for naming was larger than that of lexical decision, but the difference between them did not reach statistical significance (p = .087).

Simplified vs. Traditional Characters

The written form of characters did not moderate the magnitude of constituent effects (p = .111). This means that the constituent effects for compound words written in traditional characters (g_{rm} = 0.26, 95% CI [0.20, 0.32], p < .001) and simplified characters (g_{rm} = 0.20, 95% CI [0.16, 0.24], p < .001) were similar. Significant heterogeneity remained after accounting for writing system, $Q_E(266)$ = 1414.75, p < .001.

Publication Year

Our meta-analysis showed decreasing effect sizes over time, suggesting that more recent studies have reported smaller constituent effect sizes (b = −0.06, t = −3.51, p < .001). After controlling for publication year, the overall effect was similar in size and remained significant, g_{rm} = 0.22, 95% CI [0.18, 0.25], $t(137)$ = 12.86, p < .001.

Orthographic, Phonological, and Semantic Constituent Effects

To help determine at which processing level(s) the constituent effects might occur, we examined two tasks, primed lexical decision and reading with a boundary paradigm, that have employed manipulations that appear to be sensitive to orthographic, phonological, and/or semantic processing. We also conducted meta-analyses on two commonly reported ERP components, the N200 and N400, to examine the time course of constituent effects during compound-word processing and thereby determine if constituent effects reflect orthographic or semantic activation.

Levels of Processing

Table 1 shows how the processing level of each manipulated variable was coded in our meta-analysis. As shown, nine of the 16 manipulations targeted orthographic processing (i.e., morpho-orthography in priming/preview studies, number of strokes), phonological processing (i.e., morpho-phonology in priming/preview studies, homophone density, number of pronunciations), or semantic processing (i.e., morpho-semantics in priming/preview studies, plausibility, transparency, number of meanings). However, the processing level(s) of another six manipulations were difficult to specify and were thus not included in the analysis.

Additional analyses based on a subset of data involving 138 effect sizes revealed significant constituent effects for all three processing levels (all g_{rm}s > 0.15, *p*s < .001), indicating that orthographic, phonological, and semantic properties of the constituents affect the processing of Chinese compound words. A moderator analysis showed that the differences among the three processing levels were not significant, $F(2, 135) = 2.85$, $p = .062$; however, the effect size for phonological processing was significantly smaller than that for orthographic processing ($p = .027$). Significant unexplained variance remained between all effect sizes after accounting for processing level, $Q_E(135) = 434.45$, $p < .001$.

Priming and Preview Paradigms

Although most priming experiments have manipulated the relationship between prime and target words (e.g., their morpho-orthographic, morpho-phonological, and morpho-semantic relatedness; X. Zhou et al., 1999), several have instead manipulated the properties of the target words, such as morpheme type or semantic transparency (e.g., Peng et al., 1994; Tsang & Chen, 2014). Nevertheless, overall morphological priming effects can be examined through comparisons with the unrelated control condition (e.g., X. Zhou et al., 1999). Because the former three types of priming use a similar approach to localize the processing level(s) mediating constituent priming (see Table 1 for details and examples), our analysis focused on these three types of priming. The results of our meta-regression showed small effects for morpho-orthographic (g_{rm} = 0.27, 95% CI [0.20, 0.35], $p < .001$), morpho-phonological (g_{rm} = 0.12, 95% CI [0.01, 0.23], $p = .035$), and morpho-semantic (g_{rm} = 0.22, 95% CI [0.15, 0.29], $p < .001$) priming; only the difference between morpho-orthography and morpho-phonology was significant ($p = .024$). Moreover, results of additional analyses implied that, when including the level of morphology, the effect size for morphological priming (g_{rm} = 0.44, 95% CI [0.35, 0.52], $p < .001$) was significantly larger than that for morpho-orthographic, morpho-phonological, and morpho-semantic priming (all *p*s < .005).

In reading studies using the preview (i.e., boundary) paradigm, the processing level of the first constituents of target compound words has been examined by manipulating the morpho-orthographic, morpho-phonological, and morpho-semantic consistency between the previews and targets. The results of a meta-regression showed that the magnitude of the constituent effects using these different types of preview manipulations were similar, $F(2, 17) = 1.21$, $p = .324$. Furthermore, morpho-orthographic (g_{rm} = 0.37, 95% CI [0.14, 0.60], $p = .004$) and morpho-semantic preview (g_{rm} = 0.21, 95% CI [0.06, 0.37], $p = .009$) yielded significant constituent effects, while the overall effect size of morpho-phonologic preview was not significant (g_{rm} = 0.17, 95% CI [−0.01, 0.36], $p = .065$). These results thus again demonstrate constituent effects on the orthographic and semantic processing levels.

ERP Experiments

Several studies have recently used ERPs to explore the time course of compound-word processing in Chinese reading (e.g., Chen et al., 2017; Wei et al., 2023). The high temporal resolution of ERPs, coupled with the sensitivity of specific ERP components (e.g., N170 and N400) to orthographic, phonological, and semantic processing can provide unique insights into the time course of these different types of processing. Moreover, a recent ERP mega-study of Chinese word processing (Tsang & Zou, 2022) has also provided evidence of rapid semantic processing (e.g., effects of semantic transparency) by 200 ms. To enhance our understanding of these processes, we have aggregated evidence from these ERP studies and focused on two time-windows: 200 ms and 400 ms. Given that ERP research employs a fundamentally different approach than the studies reviewed earlier, we conducted a separate meta-analysis on ERP data. Detailed information on this meta-analysis is available in Supplementary Materials 3.

Components at ~200 ms. We extracted 32 effect sizes from 12 articles reporting 12 experiments. The overall effect size was small but significant, $g_{rm} = 0.18$, 95% CI [0.11, 0.27], $t(31) = 5.05$, $p < .001$, 90% prediction interval [−0.09, 0.45]. This finding indicates that, if a compound word is primed by a morphologically-related prime word or a compound word contains a high-frequency character, then there is an amplitude reduction around 200 ms after the onset of target word. There was substantial heterogeneity in the effect sizes, $Q_E(31) = 63.38$, $p < .001$. An LRT revealed significant within-sample variance, σ^2(Level 2) = .024, $\chi^2(1) = 5.88$, $p = .015$, indicating a heterogeneous effect size distribution. However, the between-sample variance was not significant, σ^2(Level 3) < .001, $\chi^2(1) < .001$, $p > .999$.

Moderator analysis was conducted for manipulations in primed lexical decision, which was assessed using morpho-orthographic, morpho-semantic, and morphological priming[12]. In the subgroup analysis, constituent effects were significant at three levels (morpho-orthographic: $g_{rm} = 0.29$, 95% CI [0.13, 0.47], $p = .001$; morpho-semantic: $g_{rm} = 0.19$, 95% CI [0.03, 0.36], $p = .022$; morphological: $g_{rm} = 0.30$, 95% CI [0.14, 0.46], $p < .001$). Additionally, the effect sizes were not moderated by processing level, publication year, publication language, or writing system (*p*s > .173).

Components at ~400 ms. We extracted 41 effect sizes from 15 articles reporting 15 experiments. The overall effect size was small-to-medium, $g_{rm} = 0.22$, 95% CI [0.10, 0.34],

[12] Studies manipulating morpho-phonology were fewer than four and thus they were excluded.

$t(40) = 3.74$, $p < .001$, 90% prediction interval [−0.20, 0.64]. This indicates that, when a compound word is primed by a morphologically-related prime word or a compound word contains a semantically transparent morpheme, there is an amplitude reduction around 400 ms after the onset of target word. There was substantial heterogeneity in the effect sizes, $Q_E(40) = 140.45$, $p < .001$. An LRT revealed significant within-sample variance, σ^2(Level 2) = .032, $\chi^2(1) = 12.35$, $p < .001$, indicating a heterogeneous effect size distribution. However, an LRT did not reveal significant between-sample variance, σ^2(Level 3) = .027, $\chi^2(1) = 3.16$, $p = .075$.

Further moderator analyses assessed whether word-presentation method, manipulation, processing level, writing system, and/or publication year significantly moderated the constituent effect. For presentation methods, the constituent effect for priming was larger than that for single-word presentation, $F(1, 36) = 6.85$, $p = .013$, with a significant effect for priming ($g_{rm} = 0.31$, 95% CI [0.18, 0.43], $p < .001$) but a nonsignificant effect for single-word presentation ($g_{rm} = 0.02$, 95% CI [−0.16, 0.20], $p = .789$). For manipulations, there were significant differences among morpho-orthographic priming, morpho-semantic priming, morphological priming, and the number of meanings, $F(3, 26) = 6.14$, $p = .003$. This suggests constituent effects from both the orthographic and semantic levels, with related priming conditions producing more benefit (i.e., reducing the N400) than the control condition. The effect sizes were significant for the first three manipulations (ps < .009), but not for number of meanings ($p = .914$). Writing system, publication language, and publication year did not significantly affect the strength of the constituent effect (ps >.063).

Manipulations of Constituent Properties

The effect size estimates for different constituent properties within each task are shown in Table 6 and Figure 4. The aggregate effect of character frequency, based on 35 experiments employing various tasks, was significant ($g_{rm} = 0.10$, 95% CI [0.03, 0.17], p

= .007). However, there was only evidence for a character-frequency effect in naming (g_{rm} = 0.41, 95% CI [0.11, 0.70], p = .008), but not in the lexical decision or reading tasks (both g_{rm}s < .14, ps > .153). The aggregate effect of neighborhood size was significant across tasks of lexical decision, naming, and reading (g_{rm} = 0.25, 95% CI [0.10, 0.40], p = .001). However, none of these tasks had a sufficient number of effect sizes to allow separate analyses. The effect of position probability was not significant, either in the overall estimate (g_{rm} = 0.09, 95% CI [−0.03, 0.21], p = .124) or within any individual task (both g_{rm}s < .14, ps > .061). Experiments manipulating the number of strokes did not show significant constituent effects (g_{rm} = .21, 95% CI [−0.02, 0.44], p = .070). Finally, the analyses of semantic properties indicated an effect of their semantic transparency (g_{rm} = .20, p = .019) but no effects of their number of meanings (g_{rm} = 0.11, 95% CI [−0.08, 0.30], p = .262). For other manipulations (i.e., contextual diversity, morpheme type, number of pronunciations, homophone density, and semantic plausibility), there were not sufficient effect sizes to make reliable estimates.

Discussion

Although the functional roles of constituents versus whole words in compound-word processing has been of long-standing interest (e.g., Taft & Forster, 1975, 1976), the question of how compound words are identified has garnered interest with the growing appreciation that research on this topic has been largely limited to languages using alphabetic scripts (Li et al., 2022; Reichle & Yu, 2023; see also Share, 2008). As noted, the Chinese language has its unique writing system that provides an ideal forum for addressing this question because most words consist of two constituent characters. That being the case, the present meta-analysis combined evidence from individual experiments investigating constituent effects to provide new insights into the complex nature of Chinese compound-word processing. By incorporating 268 constituent effects from 139 experiments, our analysis revealed a small but significant overall constituent effect with substantial heterogeneity across experiments.

Further analyses revealed three major novel findings: (1) constituent effects were observed irrespective of whether compound words were presented in isolation or embedded in sentences, but the former effects was significantly larger; (2) constituent effects were significant for experimental manipulations that affected the orthographic, phonological, and semantic processing of words; and (3) the characteristics of the semantic transparency, neighborhood size, and character frequency affected compound-word processing. The next sections will discuss each of the findings in turn, as well as their theoretical implications.

Compound-Word Processing in Isolation vs. Sentences

Given that the results of at least a few eye-tracking experiments have been interpreted to suggest that compound words are processed holistically during sentence reading (Shen et al., 2018; Yang et al., 2012; Zhou & Li, 2021), one obvious question is: Are compound words processed differently in sentences compared to in isolation? The present meta-analysis provides a tentative answer to this question by showing that constituent effects were significant for compound words presented using either method, although the effect was larger for words displayed in isolation than words displayed in sentences. This difference may reflect the nature of the tasks used to examine compound-word processing in the two presentation methods, with tasks like lexical decision and naming being used with isolated words and natural reading being used with compound words displayed in sentences.

For example, the findings of null constituent effects in reading come from studies that manipulated the plausibility of compound words and the initial constituents—a manipulation that may have emphasized the post-lexical integration of the words (Yang et al., 2012). Such manipulations may consequently attenuate the effects of constituent processing because non-lexical information related to both sentence and discourse processing may have facilitated word processing, providing additional support that would be unavailable with tasks like lexical decision or naming. If this interpretation is correct, then readers may be less reliant upon the processing of a compound word's constituents during natural reading because the word's identification is supported by the sentences in which they are embedded. Additionally, more cognitive resources might be recruited to support working memory, semantic integration, and sentence comprehension during reading in addition to the identification of words. According to this account, studies presenting compound words in isolation versus sentences may be investigating different stages of word processing, thereby overestimating or underestimating the magnitude of constituent effects, respectively. Future research should therefore carefully consider this important methodological factor (i.e., presenting words in isolation vs. sentences) to better understand how sentence-level information might be used to support the processing of compound words.

Another possible interpretation of the aforementioned difference is related to word segmentation in Chinese. A key distinction between identifying words in isolation versus natural reading is related to the demands of segmentation. With isolated presentation, there is no need to segment a word from surrounding characters because processing is restricted to only two characters, allowing the constituents to play a more prominent role in processing. In contrast, during sentence reading, readers must locate and segment meaningful character strings from text. For example, according to the CRM (Li & Pollatsek 2020), word segmentation happened with recognition, with word-level representations receiving the most activation and their constituents being only briefly activated during the early stages of processing. Thus, if this description is approximately correct, then compound-word constituents should play a small and secondary role in compound-word recognition, with the activated word representation playing a much more prominent role. The CRM thus provides a natural account for why constituents play a more prominent role in isolated word identification.

Orthographic, Phonological, and Semantic Processing

Our meta-analysis attempted to identify those manipulations that affect the processing of constituents at the orthographic, phonological, and semantic levels. Although this was not an easy task, there is some consensus about how the different manipulations specifically target the different levels of lexical processing. For example, a constituent's number of strokes is the variable affecting orthographic processing (e.g., Cao et al., 2023; Liu et al., 2007). Similarly, a constituent's homophone density and number of pronunciations affect phonological processing (e.g., Liu et al., 2007; Tse et al., 2022), while its semantic transparency, semantic plausibility, and number of meanings affect semantic processing (e.g., Liu et al., 2007; Tse et al., 2022; Tse & Yap, 2018). Our meta-analysis generally indicated that manipulations of these orthographic, phonological, and semantic variables affected compound-word processing.

Our meta-analysis provided evidence that constituent orthographic information becomes available during compound word processing. This small but reliable effect was evident in both morpho-orthographic priming and preview experiments (e.g., Tsang et al., 2021; Zhou et al., 1999). The findings suggest that, when the orthographic (and possibly phonological) forms of the prime/preview constituents are activated, this activation facilitates the subsequent processing of the compound words. And because the meanings of the constituents differ between the primes and targets, these effects cannot be due to semantic processing. Finally, our meta-analysis suggests that effects of number of strokes and position probability on compound-word processing are limited.

Our meta-analysis also provided evidence that constituent phonological information becomes available during compound-word processing. There were reliable morpho-phonological priming and preview effects, with more rapid identification of compound words when they were preceded by a different character sharing the same pronunciation as the compound words (e.g., Pan et al., 2016; Tan & Peng, 1991). These results indicate that the phonological forms of the prime/preview characters are activated, and that this facilitates the subsequent processing of the compound words. These results also nicely illustrate how phonological information becomes available in a rapid and largely automatic manner despite the ambiguous grapheme-to-phoneme mappings in Chinese.

Finally, our meta-analysis provided evidence that constituent semantic information also becomes available during compound-word processing, and the effects were statistically significant in studies manipulating morpho-semantic prime/preview (e.g., Tsang et al., 2014; Yan et al., 2012; Zhou et al., 1999) and semantic transparency (e.g., Tsang & Chen, 2014). Although the bulk of our evidence for semantic effects was garnered from priming experiments (Tsang et al., 2014; Tsang & Chen, 2013; Zhao et al., 2021), these experiments are inherently limited because two compound words that share a morpheme are often related in meaning, making it difficult to know if the observed priming effects are due to constituent or whole-word processing. However, one eye-tracking study using the boundary paradigm clearly illustrates this difficulty (Shen et al., 2018). In Shen et al., the first constituent of preview and target words were the same character, functioning as an ambiguous morpheme with both dominant and subordinate meanings. They manipulated whole-word semantic similarity and morpho-semantic similarity between preview and target words. The results showed that the fixation durations on the target word were shorter when the morpheme meanings were the same rather than different, but this effect emerged only when the preview and target words were semantically related. Their results suggest that whole-word meaning plays a critical role in processing Chinese compounds, with whole-word access serving as the primary route for reading two-character compounds. Therefore, these findings imply an interaction between constituent and whole-word meaning, and underscore the dominance of whole-word representation especially when reading comprehension is emphasized.

Taken together, our findings suggest that the constituents of Chinese compound words are activated at the orthographic, phonological, and semantic levels, consistent with the hypothesis that constituents are represented at each of these three levels (Tan & Perfetti, 1999; X. L. Zhou & Marslen-Wilson, 2000). Importantly, our evidence for the semantic processing of constituents is highly diagnostic because, although all models of Chinese reading assume some degree of orthographic and phonological processing, the semantic processing of constituents is seemingly inconsistent with holistic models (e.g., Packard, 1999; Smith et al., 2021) but a prerequisite for compositional models (e.g., Taft et al., 1999; Taft & Zhu, 1997).

Manipulations Affecting Multiple Processing Levels

Although the preceding discussion focused on effects that can be localized to one of the three lexical processing stages, many variables cannot be unambiguously localized and may affect processing at two or more stages. For example, the effects of both morphological and morphemic-relatedness priming were robust and likely reflect whole-morpheme processing at the orthographic, phonological, and semantic levels (e.g., Jia et al., 2013; X. L, Zhou et al., 1999). And manipulations of constituent properties, such as their contextual diversity, neighborhood size, and morpheme type, all induced significant constituent effects (e.g., Chen et al., 2017; Yao et al., 2022), although the specific level(s) of processing associated with these variables remain controversial.

Perhaps most importantly, however, the effects of character frequency, which have been investigated in many studies and are always interpreted as evidence for compositional processing, were significant when using naming tasks but not when using lexical decision or reading tasks in our meta-analysis. Indeed, we should note that previous studies manipulating character frequency have shown inconsistent results. For example, studies of character frequency have reported facilitation (Tse & Yap, 2018; Yan et al., 2006), inhibition (Xiong et al., 2023; Yu et al., 2021), or null effects (X. Li et al., 2014; Ma et al., 2015), or that character-frequency effects are moderated by both whole-word frequency and constituent position (Cui et al., 2021; Yan et al., 2006). Given these mixed results, it is not unexpected that the overall character-frequency effect in our meta-analysis was small. Although different interpretations of these mixed results have been offered, our meta-analysis indicated that the character-frequency effects were absent in both natural reading and lexical decision, which precludes a simple explanation based on either a difference in word-presentation methods or task demands. However, character-frequency effects *were* significant in the naming task, which arguably emphasizes character processing more than natural reading or lexical decision (see Xiong et al., 2023). Finally, the frequency variable may generate faciliatory or inhibitory effects with character versus word processing. For example, Zhang et al. (2024) showed that constituent frequency effects are facilitatory on the character level but inhibitory on the word level. For that reason, the facilitatory and inhibitory effects may cancel each other, resulting in small but inconsistent effects across different studies.

Of course, complicating this account is that other experiments have also demonstrated that the character-frequency effect is modulated by factors such as constituent neighborhood size and transparency (Taft et al., 1994; Peng et al., 1999). For example, Peng et al. (1999) found that the character-frequency effect was modulated by transparency, with a positive effect for transparent words and a negative effect for opaque words. Based on these findings, Peng et al. argued that, for opaque compounds, sematic activation at the word level was attenuated due to active competition among the meanings of their individual characters. Such studies therefore suggest that the mixed findings regarding character frequency may be due to factors such as neighborhood size and transparency not being well controlled. Based on the results of the current meta-analysis, we could not rule out this possibility because the studies included seldom reported whether they controlled neighborhood size or semantic transparency.

CRM (X. Li & Pollatsek, 2020) provides one possible account for the finding of the limited effect of character frequency. According to this model, compound words are identified via an active competition of nodes representing single- and multi-character words. For example, if the word being identified is a compound word (e.g., 人群, meaning *a lot of people*), then a node representing the word normally “wins” this competition because it receives the most activation from nodes representing its constituent characters (i.e., activation from the 人 node, meaning *people*, and the 群 node, meaning *swarm*). The model simulations show that word nodes receive the most activation with compound word characters obtaining only fleeting activation in the initial stages of word recognition. Thus, compound word constituents have a small and secondary role in compound word recognition, while the activated word representation plays the key role.

Other Moderators

Our meta-analysis examined other potential moderators of constituent effects, including whole-word frequency (see Appendix B for results), whether the compound words were displayed using simplified or traditional characters, as well as the publication year and type (i.e., journal articles vs. other sources) of the included studies. Our results suggest that none of these variables significantly moderated constituent effects. The exception was publication year, with the magnitude of the constituent effect becoming smaller over time. This may reflect general changes within the field of Chinese language research, such as increasing quality of the experiments or statistical methods. We did not find the moderating effects of whole-word frequency, which is inconsistent with the findings in some individual experiments (e.g., Yu et al., 2021). Moreover, constituent effects were absent when considering whole-word frequency, for both high- and low-frequency words. These results demonstrate that whole-word representations are likely to dominate the identification of compound words, while constituents have little role to play, as suggested by both the CRM (Li & Pollatsek, 2020) and CEZR (Liu et al., 2024). Nonetheless, the findings should be treated cautiously given the limited number of effect sizes in this analysis. Finally, the results of our publication bias analysis could not rule out some degree of publication bias in experiments investigating constituent effects due to some asymmetry in the overall funnel plot and the heterogeneity across experiments.

Implications

The preceding pattern of results is admittedly complex. For that reason, the final sections of this article will discuss the implications of our results for four broad theoretical and practical topics: (1) the evaluation and development of models of Chinese reading; (2) the understanding of how structural differences between logographic and alphabetic scripts might differentially affect compound word processing; (3) the design of future experiments to examine Chinese compound-word processing; and (4) the teaching of the Chinese language.

Models of Chinese Reading

Although most "models" of Chinese reading are either verbal theories that cannot be rigorously evaluated or limited to simulating the identification of single characters (see Reichle & Yu, 2018), one important theoretical implication of our meta-analysis is that these models must be able to explain why the processing of compound words is affected by properties of both the words themselves and their constituents. Additionally, models must explain why constituents of compound words in isolation tend to produce larger effects than constituents of compound words in sentences, and why the constituent effects are not moderated by the whole-word properties. Any complete model of reading (e.g., CRM: Li & Pollatsek, 2020; CEZR: Liu et al., 2024) must of course also explain why information provided by sentences facilitates the processing of compound words. Finally, due to the inherent complexity of both the effects and the models, the accounts provided by the latter must be in the form of actual simulations—verbal accounts are simply not sufficient to guarantee that any explanation that is provided will be accurate (Hintzman, 1991).

Because two of the authors of this article have been involved in the development of the aforementioned CRM and CEZR models, it would be amiss not to at least comment on the more direct implications of our findings for those two models. For example, the CRM proposed by Li and Pollatsek (2020) provides a novel account of how compound words are processed in Chinese reading. Because the CRM adopts an interactive-activation framework (see McClelland & Rumelhart, 1981), it posits that words are processed through a network of nodes that represent three distinct types of information: visual, character, and word. The model also posits that, when processing a compound word, all of the character nodes within the perceptual span will become active, which will then activate all of the word nodes that can be formed from those characters, including both single-character and compound words. These activated word nodes then compete with each other until the activation of one exceeds a threshold, causing the word that it represents to be identified. Because compound words will receive activation from more character nodes than single-character words, the former typically win the competition, allowing compound words to be identified in a holistic manner. But because character nodes and the nodes of single-character words are both activated, the properties of individual characters can influence the time required to identify compound words. The CRM can therefore accommodate both the whole-word effects and constituent effects that have been documented in previous studies. By this account, holistic versus constituent processing may not be opposing processes, but rather aspects of lexical processing that occur within a single framework. However, it is important to acknowledge that, because the CRM does not implement phonological or semantic processing, it cannot explain findings related to those types of processing. Clearly, further research is needed to understand if and/or how those findings might be accommodated with the CRM framework.

The CRM also provides a tentative account of the mixed findings that have been reported for constituent effects, such as reports of positive, null, and negative effects of character frequency on compound word processing. According to the model, such effects should occur because of two countermanding tendencies: (1) high-frequency characters tend to be processed more rapidly than low-frequency characters, thereby contributing to a net positive character-frequency effect; (2) single-character words tend to be higher in frequency than multi-character words, thereby producing more intra-lexical competition and contributing to a net negative character-frequency effect. The CRM would thus predict that the relative balance of these two opposing factors would determine the sign of the character-frequency effect and the mixed effects that have been reported in the literature.

Turning now to the CEZR proposed by Liu et al. (2024; see also Yu et al., 2021), it is important to first note that this model, in contrast to the CRM, does not provide a detailed account of how Chinese words are actually processed and identified. The CEZR instead only describes how variables related to each word (e.g., its frequency, predictability, etc.), in combination with a heuristic that evaluates the familiarity of each possible grouping of characters within a four-character focus of attention, is used to determine which characters will be segmented in identifying the word, and how long this processing will take. Consequently, although the model does not specify the actual mechanics of word identification, it is broadly consistent with our findings that constituent properties affect compound word processing. However, the evidence that the semantic constituent properties (e.g., transparency; Han et al., 2014; Lee et al., 2021; Y. Wu & Li, 2018) affect gaze durations on compound words during reading has an important ramification because it strongly constrains the nature of character familiarity as posited in the model—that it varies as a function of meaning and not just, for example, orthographic form. That being said, whether or not this general prediction can be leveraged into a more concrete experiment and thus used to test the model is a task for another day.

Script Influences on Compound Word Processing

Compound-word processing reveals significant differences between Chinese and alphabetic languages. These differences are rooted in the distinct characteristics of their respective writing systems, which in turn influence how words are processed and identified. For example, in Chinese, which has a logographic script, compound words are usually composed of two characters that each represent a morpheme having a specific meaning. The results of priming and preview experiments reviewed in our meta-analysis suggest that morpho-semantics becomes available rapidly and obligatorily during Chinese compound-word processing. For example, a series of experiments varying the SOA to investigate the time course of morpho-semantic processing demonstrated that compound words sharing morphemes produced stronger priming effects than those sharing only characters, indicating the early activation of semantic information (e.g., Zhou et al., 1999). There is also evidence of rapid morpho-semantic processing for both transparent and opaque compound words (Tsang & Chen, 2014).

In contrast, the processing of morphologically complex words in alphabetic languages is predominantly sensitive to orthographic properties. For example, Rastle et al. (2004) investigated the role of semantic information in processing the words with suffixes and found that the early stages of word identification were primarily influenced by the orthographic properties of the constituents. This suggests that, in the reading of alphabetic scripts, morphological processing, including the activation of semantic information, occurs subsequent to orthographic processing. One reason for this is that the processing of alphabetic compound words may necessitate that the words are first decomposed into their constituent morphemes because the boundaries of those constituents are not explicitly marked (as they are in Chinese). This conjecture is consistent with the findings from a priming experiment using magnetoencephalography (*MEG*) that support morphological decomposition of English compound words (Brooks & Cid de Garcia, 2015); based on these results, the authors concluded that decomposition was independent of semantics, and that the meanings of morphemes were combined in a later stage, but only if the words were semantically transparent. However, from another perspective, the lack of clear morpheme boundaries in alphabetic languages may necessitate earlier morpheme meaning access to facilitate the decomposition procedure. It is important to note that other studies of alphabetic languages have reported evidence for early morpho-semantic effects in the processing of derived and inflected words, two other types of complex words composed of multiple morphemes (e.g., Diependaele et al., 2011; Feldman et al., 2009, 2010, 2015). One possible explanation is that the morphemes are often salient due to orthographic features (e.g., Taft & Nguyen-Hoan, 2010), even in the absence of explicit boundaries. Such features may therefore allow orthographic segmentation to be completed rapidly, which may then allow rapid access to morpho-semantic information.

These possible differences related to how compound words are processed in Chinese versus languages that use alphabetic scripts probably reflect inherent visual and/or structural differences in the two types of writing systems. For example, in Chinese, individual characters are distinct units having clear boundaries, facilitating the rapid identification of morphemes without the need to first decompose the word into its constituents. Words written in alphabetic scripts, on the other hand, usually consist of continuous letter strings, necessitating some type of orthographic analysis to segment the words into their morphemes prior to accessing their meanings. Further illustrating this difference, Li et al. (2022) showed how visual length and morpheme segmentation influence compound-word processing: In logographic scripts like Chinese, the segmentation of morphemes is more straightforward due to the clear demarcation of characters, whereas in alphabetic scripts, word length and the absence of explicit morpheme boundaries make orthographic processing more critical. This difference suggests that different cognitive strategies are employed by readers of different writing systems: Chinese readers are likely to rely more on direct semantic activation facilitated by distinct morpheme boundaries, whereas readers of alphabetic languages may rely upon orthographic cues to first decompose compound words and then access the meanings of their constituents. This fundamental difference highlights how human cognition adapts to various linguistic structures.

Future Experiments

Further empirical work is clearly required to better understand how experimental tasks and word-presentation methods affect compound-word processing. Although our meta-analysis suggested the important role of how compound words are displayed, this variable is obviously confounded with the experimental task in that, for example, natural reading requires target words to be displayed within the contexts of whole sentences. Future efforts might therefore be directed towards de-confounding these two variables, perhaps by using methods like *rapid visual serial presentation* (*RSVP*) that afford a more "natural" reading of compound words than words displayed in isolation. This method would allow the obtained results to be directly compared with natural reading, on one hand, and lexical decision, priming, and naming, on the other.

Another critical issue is whether constituent effects reflect composition or simply the activation of constituent. Although most studies suggest that morphemic semantic information is activated, few provide direct evidence that compound-word meanings are composed of constituent meanings (e.g., Tsang & Chen, 2013). The "traditional" view of compound-word processing (e.g., Taft & Forster, 1975, 1976) interpreted early constituent effects as evidence for composition. However, alternative mechanisms have also been proposed to explain the early constituent effects. For example, some studies have suggested that constituent and whole-word semantic representations are activated simultaneously, with morphological processing arising from the interaction between them (Zhou & Marslen-Wilson, 2000; Zhou et al., 1999). Given the complex relationship between constituent and whole-word representations, especially at the semantic level, future studies are needed to directly test whether readers compose word meanings from morphemes.

Finally, although we identified some factors that significantly moderated constituent effects, the substantial heterogeneity observed suggests that additional moderators remain unexplored. One such factor is semantic transparency, which was found to play an important role in compound word processing (Peng et al., 1999). Unfortunately, we were unable to assess this moderator because few studies reported semantic transparency for their materials or examined its interaction with other variables. Future research is therefore required to examine additional moderators, to explore the possible interactions between orthographic and semantic processing during compound-word identification, and to clarify how properties at both the whole-word and constituent levels affect compound word processing.

Educational Practice

Our meta-analytic findings on constituent effects in Chinese compound-word processing have implications for language instruction. For novel compound words, understanding the role of morphemic constituents can enhance the efficiency of vocabulary acquisition. Educators should therefore design targeted exercises that emphasize the identification and understanding of individual morphemes at orthographic, phonological, and semantic levels. This approach is particularly useful in Chinese, where characters often carry distinct meanings, thereby enabling learners to build a robust vocabulary through morpheme-based instruction.

In the case of identifying lexicalized compound words, if different properties of constituents play different roles, then additional meta-analyses might be required to provide insights into whether and how constituents affect compound-word processing. By identifying specific characteristics that affect lexicalized word processing, educators might be able to tailor their teaching methods to address these nuances. For example, if certain morphemic properties are found to facilitate the identification and comprehension of compound words, then instructional materials can incorporate these properties to support learning. This targeted approach can improve the overall efficiency of Chinese language learning, helping students to better grasp the complex morphology of the language.

Overall, our meta-analytic findings on constituent effects have significant practical implications for language instruction. By leveraging the insights gained from the reviewed experiments, educators can enhance word acquisition training, improve comprehension of both novel and lexicalized compound words, and ultimately increase the efficiency of Chinese language learning.

Limitations

In closing this discussion, it is important to acknowledge that our meta-analyses have several limitations. First, our meta-analytic methods presupposed independent effect sizes even though approximately a third of the included experiments provided multiple effect sizes. Second, all the included experiments used university students as participants, limiting the generalizability of our findings to other populations (e.g., readers having different educational backgrounds or from different age groups). Third, our different methods for detecting publication bias yielded mixed results and were less reliable when heterogeneity was high. Therefore, we should be cautious when interpreting the publication bias findings. Finally, the significant moderator that was identified in our meta-analysis, word-presentation method, was often confounded with certain manipulations, making it difficult to disentangle their effects. However, when we only included those manipulations that were used in studies both with and without sentences (totaling 8 manipulations and 239 effect sizes), the moderating effects of presentation method was still significant, $F(1, 237) = 14.14$, $p < .001$. Despite these limitations, it is important to note that our meta-analyses have none-the-less clarified the functional role of constituent processing in the identification of Chinese compound words.

Conclusion

This meta-analysis of constituent effects provides important new insights into how Chinese compound words are processed and identified. By synthesizing three decades of empirical evidence on processing of Chinese compound words, our findings suggest that the processing of individual constituents has a small but significantly positive impact on the processing of compound words. Moreover, constituent effects were observed at the orthographic, phonological, and semantic processing levels, and they were observed in both sentence reading and when words are presented in isolation, suggesting that the constituent effect is robust during Chinese reading. However, the small magnitudes of the constituent effects, as well as the null constituent effects when using plausibility paradigms, suggest that readers might use different processing strategies during word identification and word integration. Although these results suggest that the constituents of compound words are activated during word identification, compound words are processed as a whole unit during integration. These findings are important for understanding how compound words are processed in Chinese and also shed light on universal mechanisms of compound-word processing across languages by demonstrating how a language’s script can influence the cognitive mechanisms that support compound-word processing. Finally, the present study showed substantial heterogeneity across multiple analyses, so the averaged effect sizes should be interpreted with caution. Future studies with additional exploratory diagnostics should be conducted to clarify the sources of variabilities across studies.

References

Asterisks indicate those studies that were included in our meta-analysis.

Aguinis, H., Gottfredson, R. K., & Joo, H. (2013). Best-practice recommendations for defining, identifying, and handling outliers. *Organizational Research Methods, 16*(2), 270–301. https://doi.org/10.1177/ 1094428112470848

Andrews, S. (1997). The effect of orthographic similarity on lexical retrieval: Resolving neighborhood conflicts. *Psychonomic Bulletin & Review*, *4*(4), 439–461. https://doi.org/10.3758/BF03214334

Assink, M., & Wibbelink, C. J. (2016). Fitting three-level meta-analytic models in R: A step-by-step tutorial. *The Quantitative Methods for Psychology, 12*(3), 154–174. https://doi.org/10.20982/tqmp.12.3.p154

Brooks, T. L., & Cid de Garcia, D. (2015). Evidence for morphological composition in compound words using MEG. *Frontiers in Human Neuroscience*, *9*. https://doi.org/10.3389/fnhum.2015.00215

*Cao H., Lan Z., Gao F., Yu H., Li P., & Wang J. (2023). The role of character positional frequency on word recognition during Chinese reading: Lexical decision and eye movements studies. *Acta Psychologica Sinica*, *55*(2), 159. https://doi.org/10.3724/SP.J.1041.2023.00159

*Chen, L., Fang, X., & Perfetti, C. A. (2017). Word-to-text integration: ERP evidence for semantic and orthographic effects in Chinese. *Journal of Neurolinguistics*, *42*, 83–92. https://doi.org/10.1016/j.jneuroling.2016.11.010

*Chen, L., Xu, Y., & Perfetti, C. (2023). A character-word dual function model of reading Chinese: Evidence from reading Chinese compounds. *Reading and Writing*. https://doi.org/10.1007/s11145-023-10478-4

*Chen, Q., Zhao, G., Huang, X., Yang, Y., & Tanenhaus, M. K. (2017). The effect of character contextual diversity on eye movements in Chinese sentence reading. *Psychonomic Bulletin & Review*, *24*(6), 1971–1979. https://doi.org/10.3758/s13423-017-1278-8

Chang, Y.-N., Welbourne, S., & Lee, C.-Y. (2016). Exploring orthographic neighborhood size effects in a computational model of Chinese character naming. *Cognitive Psychology*, *91*, 1–23. https://doi.org/10.1016/j.cogpsych.2016.09.001

Chen, L., Xu, Y., & Perfetti, C. (2023). A character-word dual function model of reading Chinese: Evidence from reading Chinese compounds. *Reading and Writing*. https://doi.org/10.1007/s11145-023-10478-4

Chen, X., Zhang, J., & Shu, H. (2006). The semantic activation of color morphemes in opaque compound words. *Journal of Psychological Science*, *29*(6), 1359–1363. https://doi.org/10.16719/j.cnki.1671-6981.2006.06.018

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences (2nd ed.)*. Hillsdale, NJ: Lawrence Earlbaum Associates.

Coles, N. A., Larsen, J. T., & Lench, H. C. (2019). A meta-analysis of the facial feedback literature: Effects of facial feedback on emotional experience are small and variable. *Psychological Bulletin*, *145*(6), 610–651. https://doi.org/10.1037/bul0000194

*Cong, F. (2019). *The influence of semantic relation on lexical recognition for Chinese compound* [Master degree]. Shandong Normal University.

*Cui, L., Wang, J., Zhang, Y., Cong, F., Zhang, W., & Hyona, J. (2021). Compound word frequency modifies the effect of character frequency in reading Chinese. *Quarterly Journal of Experimental Psychology*, *74*(4), 610–633. https://doi.org/10.1177/1747021820973661

*Cui, L., Yan, G., Bai, X., Hyönä, J., Wang, S., & Liversedge, S. P. (2013). Processing of compound-word characters in reading Chinese: An eye-movement-contingent display change study. *Quarterly Journal of Experimental Psychology, 66*(3), 527–547. https://doi.org/10.1080/17470218.2012.667423

Diependaele, K., Duñabeitia, J. A., Morris, J., & Keuleers, E. (2011). Fast morphological effects in first and second language word recognition. *Journal of Memory and Language, 64*(4), 344-358. https://doi.org/10.1016/j.jml.2011.01.003

*Ding, G., & Peng, D. (2006). The relationship between whole word and lexeme in processing Chinese reversible words. *Contemporary Linguistics*, *8*(1), 36–45.

*Du, Y. (2021). *The influence of Semantic Transparency on Chinese Reading and its Age Difference* [Master degree]. Tianjin Normal University.

Duval, S., & Tweedie, R. (2000). Trim and fill: A simple funnel-plot–based method of testing and adjusting for publication bias in meta-analysis. *Biometrics*, *56*(2), 455–463. https://doi.org/10.1111/j.0006-341X.2000.00455.x

Feldman, L. B., Kosti, A., Basnight-Brown, D. M., Urevi, D. F., & Pastizzo, M. J. (2010). Morphological facilitation for regular and irregular verb formations in native and non-native speakers: Little evidence for two distinct mechanisms. *Bilingualism, 13*(2), 119–135. https://doi.org/10.1017/S1366728909990459

Feldman, L. B., Milin, P., Cho, K. W., Moscoso Del Prado Martín, F., & O'Connor, P. A. (2015). Must analysis of meaning follow analysis of form? A time course analysis. *Frontiers in Human Neuroscience, 9*, 1–19. https://doi.org/10.3389/fnhum.2015.00111

Feldman, L. B., O'Connor, P. A., del Prado, M., & Martín, F. (2009). Early morphological processing is morphosemantic and not simply morpho-orthographic: A violation of form-then-meaning accounts of word recognition. *Psychonomic Bulletin & Review, 16*(4), 684–691. https://doi.org/10.3758/PBR.16.4.684

*Gao, F., Wang, J., Zhao, C. G., & Yuan, Z. (2021). Word or morpheme? Investigating the representation units of L1 and L2 Chinese compound words in mental lexicon using a repetition priming paradigm. *International Journal of Bilingual Education and Bilingualism*, *25*(7), 2382–2396. https://doi.org/10.1080/13670050.2021.1913984

*Gao, Q. (2018). *The role of character positional frequency in sentence reading and lexical naming task* [Master degree]. Tianjin Normal University.

Giraudo, H., & Grainger, J. (2001). Priming complex words: Evidence for supralexical representation of morphology. *Psychonomic Bulletin & Review*, *8*(1), 127–131. https://doi.org/10.3758/bf03196148

*Han, Y.-J., Huang, S., Lee, C.-Y., Kuo, W.-J., & Cheng, S. (2014). The modulation of semantic transparency on the recognition memory for two-character Chinese words. *Memory & Cognition*, *42*(8), 1315–1324. https://doi.org/10.3758/s13421-014-0430-1

Harrer, M., Cuijpers, P., Furukawa, T., & Ebert, D. (2021). *Doing Meta-Analysis with R: A Hands-On Guide* (1st ed.). Chapman and Hall/CRC. https://doi.org/10.1201/9781003107347

Hintzman, D. L. (1991). Why are formal models useful in psychology? In W. E. Hockley & S. Lewandowsky (Eds.), *Relating theory and data: Essay on human memory in honor of Bennet B. Murdock* (pp. 39-56). Hillsdale, NJ, USA: Erlbaum.

Hsiao, J. H., & Shillcock, R. (2004). Connectionist modelling of Chinese character pronunciation based on foveal splitting. *Proceedings of the Annual Meeting of the Cognitive Science Society*, *26*, 601–606. https://api.semanticscholar.org/CorpusID:4942234

Hsiao, J. H.-W., & Shillcock, R. (2005). Foveal splitting causes differential processing of Chinese orthography in the male and female brain. *Brain Research. Cognitive Brain Research*, *25*(2), 531–536. https://doi.org/10.1016/j.cogbrainres.2005.08.005

*Huang, C.-Y., Lee, C.-Y., Huang, H.-W., & Chou, C.-J. (2011). Number of sense effects of Chinese disyllabic compounds in the two hemispheres. *Brain and Language*, *119*(2), 99–109. https://doi.org/10.1016/j.bandl.2011.04.005

*Huang, H.-W., & Lee, C.-Y. (2018). Number of meanings and number of senses: An ERP study of sublexical ambiguities in reading Chinese disyllabic compounds. *Frontiers in Psychology*, *9*, 324. https://doi.org/10.3389/fpsyg.2018.00324

*Huang, H.-W., Lee, C.-Y., Tsai, J.-L., Lee, C.-L., Hung, D. L., & Tzeng, O. J.-L. (2006). Orthographic neighborhood effects in reading Chinese two-character words. *Neuroreport*, *17*(10), 1061–1065. https://doi.org/10.1097/01.wnr.0000224761.77206.1d

*Huang, H.-W., Lee, C.-Y., Tsai, J.-L., & Tzeng, O. J.-L. (2011). Sublexical ambiguity effect in reading Chinese disyllabic compounds. *Brain and Language*, *117*(2), 77–87. https://doi.org/10.1016/j.bandl.2011.01.003

*Hyönä, J., Cui, L., Heikkilä, T. T., Paranko, B., Gao, Y., & Su, X. (2024). Reading compound words in Finnish and Chinese: An eye-tracking study. *Journal of Memory and Language*, *134*, 104474. https://doi.org/10.1016/j.jml.2023.104474

Institute of Language Teaching and Research. (1986). *Modern Chinese frequency dictonary*. Beijing Language Institute Press.

*Jia, X., & Zhou, C. (2023). *Neural correlation of relation information: Evidence from ERP* [Preprint]. https://doi.org/10.21203/rs.3.rs-2692806/v1

*Jia, X., Wang, S., Zhang, B., & Zhang, J. X. (2013). Electrophysiological evidence for relation information activation in Chinese compound word comprehension. *Neuropsychologia*, *51*(7), 1296–1301. https://doi.org/10.1016/j.neuropsychologia.2013.03.024

Harrer, M., Cuijpers, P., Furukawa, T. A., & Ebert, D. D. (2021). *Doing meta-analysis with R.* https://doi.org/10.1201/9781003107347

Lakens, D. (2013). Calculating and reporting effect sizes to facilitate cumulative science: A practical primer for t-tests and ANOVAs. *Frontiers in Psychology*, *4*. https://doi.org/10.3389/fpsyg.2013.00863

Lee, C.-Y., Hsu, C.-H., Chang, Y.-N., Chen, W.-F., & Chao, P.-C. (2015). The feedback consistency effect in Chinese character recognition: Evidence from a psycholinguistic norm. *Language and Linguistics*, *16*(4), 535–554. https://doi.org/10.1177/1606822X15583238

*Lee, H.-J., Cheng, S., Lee, C.-Y., & Kuo, W.-J. (2021). The neural basis of compound word processing revealed by varying semantic transparency and morphemic neighborhood size. *Brain and Language*, *221*, 104985. https://doi.org/10.1016/j.bl.2021.104985

Leminen, A., Smolka, E., Duñabeitia, J. A., & Pliatsikas, C. (2019). Morphological processing in the brain: The good (inflection), the bad (derivation) and the ugly (compounding). *Cortex*, *116*, 4–44. https://doi.org/10.1016/j.cortex.2018.08.016

*Li, M.-F. (2018). *Effect of character frequency and word frequency in reading Chinese single character word and compound word: An eye movement study* [Master degree]. Shandong Normal University.

*Li, M.-F., Gao, X.-Y., Chou, T.-L., & Wu, J.-T. (2017). Neighborhood frequency effect in Chinese word recognition: Evidence from naming and lexical decision. *Journal of Psycholinguistic Research*, *46*(1), 227–245. https://doi.org/10.1007/s10936-016-9431-5

*Li, M.-F., Lin, W.-C., Chou, T.-L., Yang, F.-L., & Wu, J.-T. (2015). The role of orthographic neighborhood size effects in Chinese word recognition. *Journal of Psycholinguistic Research*, *44*(3), 219–236. https://doi.org/10.1007/s10936-014-9340-4

Li, X., Bicknell, K., Liu, P., Wei, W., & Rayner, K. (2014). Reading is fundamentally similar across disparate writing systems: A systematic characterization of how words and characters influence eye movements in Chinese reading. *Journal of Experimental Psychology: General*, *143*(2), 895–913. https://doi.org/10.1037/a0033580

Li, X., Huang, L., Yao, P., & Hyönä, J. (2022). Universal and specific reading mechanisms across different writing systems. *Nature Reviews Psychology*, *1*(3), 133–144. https://doi.org/10.1038/s44159-022-00022-6

*Lian, K. (2019). *A comparative study of Chinese college students and primary school students in lexical processes: Evidence from eye movement in loud reading* [Doctor degree]. Tianjin Normal University.

Liang, F., Blythe, H. I., Zang, C., Bai, X., Yan, G., & Liversedge, S. P. (2015). Positional character frequency and word spacing facilitate the acquisition of novel words during

Chinese children's reading. *Journal of Cognitive Psychology*, *27*(5), 594–608. https://doi.org/10.1080/20445911.2014.1000918

*Liang, F., Gao, Q., Li, X., Wang, Y., Bai, X., & Liversedge, S. P. (2022). The importance of the positional probability of word final (but not word initial) characters for word segmentation and identification in children and adults' natural Chinese reading. *Journal of Experimental Psychology: Learning, Memory, and Cognition*. https://doi.org/10.1037/xlm0001116

Libben, G. (2014). The nature of compounds: A psychocentric perspective. *Cognitive Neuropsychology*, *31*, 8–25. https://doi.org/10.1080/02643294.2013.874994

Libben, G., & Jarema, G. (Eds.). (2006). *The representation and processing of compound words*. Oxford University Press.

*Lin, Y., Qian, Q., Song, F., & Zhang, B. (2002). Does the phonemic similarity process of two-character words exist in lexical access? *Journal of Psychological Science*, *25*(4), 439–441+511. https://doi.org/10.16719/j.cnki.1671-6981.2002.04.015

*Liu, P. D., & McBride-Chang, C. (2010). Morphological processing of Chinese compounds from a grammatical view. *Applied Psycholinguistics*, *31*(4), 605–617. https://doi.org/10.1017/S0142716410000159

*Liu, X. (2017). *Parafoveal processing of Chinese compound word morpheme during Chinese reading: Evidence from boundary paradigm* [Master degree]. Fujian Normal University.

Liu, Y., Shu, H., & Li, P. (2007). Word naming and psycholinguistic norms: Chinese. *Behavior Research Methods*, *39*, 192–198. https://doi.org/10.3758/BF03193147

Liu, Y., Yu, L., & Reichle, E. D. (2024). Towards a model of eye-movement control in Chinese reading. *Psychonomic Bulletin & Review*. https://doi.org/10.3758/s13423-024-02570-9

*Liu, Z., Liu, X., Tong, W., & Fu, F. (2020). Word's contextual predictability and its character frequency effects in Chinese reading: Evidence from eye movements. *Frontiers in Psychology*, *11*, 1833. https://doi.org/10.3389/fpsyg.2020.01833

*Liu, Z., Tong W., Zhang Z., & Zhao Y. (2020). Predictability impacts word and character processing in Chinese reading: Evidence from eye movements. *Acta Psychologica Sinica*, *52*(9), 1031–1047. https://doi.org/10.3724/SP.J.1041.2020.01031

*Ma, G., Li, X., & Rayner, K. (2015). Readers extract character frequency information from nonfixated-target word at long pretarget fixations during Chinese reading. *Journal of*

Experimental Psychology: Human Perception and Performance, *41*(5), 1409–1419. https://doi.org/10.1037/xhp0000072

McClelland, J. L., & Rumelhart, D. E. (1981). An interactive activation model of context effects in letter perception: I. An account of basic findings. *Psychological Review*, *88*(5), 375–407. https://doi.org/10.1037/0033-295X.88.5.375

McKay, K. T., Grainger, S. A., Coundouris, S. P., Skorich, D. P., Phillips, L. H., & Henry, J. D. (2021). Visual attentional orienting by eye gaze: A meta-analytic review of the gaze-cueing effect. *Psychological Bulletin*, *147*(12), 1269–1289. https://doi.org/10.1037/bul0000353

Packard, J. L. (1999). Lexical access in Chinese speech comprehension and production. *Brain and Language*, *68*(1–2), 89–94. https://doi.org/10.1006/brln.1999.2102

*Pan, J., Laubrock, J., & Yan, M. (2016). Parafoveal processing in silent and oral reading: Reading mode influences the relative weighting of phonological and semantic information in Chinese. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *42*(8), 1257–1273. https://doi.org/10.1037/xlm0000242

*Pan, J., Laubrock, J., & Yan, M. (2021). Phonological consistency effects in Chinese sentence reading. *Scientific Studies of Reading*, *25*(4), 335–350. https://doi.org/10.1080/10888438.2020.1789146

*Peng, D., Ding, G., Wang, C., Taft, M., & Zhu, X. (1999). The processing of Chinese reversible words: The role of morphemes in lexical access. *Acta Psychologica Sinica*, *31*(1), 36–46.

*Peng, D., Li, Y., & Liu, Z. (1994). Identification of the Chinese two-character word under repetition priming condition. *Acta Psychological Sinica*, *26*(04), 393–400.

*Peng, D., Liu, Y., & Wang, C. (1999). How is access representation organized? The relation of polymorphemic words and their morphemes in Chinese. In J. Wang, A. W. Inhoff, & H.-C. Chen (Eds.), *Reading Chinese script: A cognitive analysis* (pp. 65–89). Erlbaum.

Pinker, S. (2000). *Words and rules: The ingredients of language*. London, UK: Phoenix.

Plaut, D. C., McClelland, J. L., Seidenberg, M. S., & Patterson, K. (1996). Understanding normal and impaired word reading: Computational principles in quasi-regular domains. *Psychological Review*, *103*, 56–115.

R Core Team. (2017). *R: A language and environment for statistical computing.* R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Rastle, K., Davis, M. H., & New, B. (2004). The broth in my brother's brothel: Morpho-orthographic segmentation in visual word recognition. *Psychonomic Bulletin & Review*, *11*(6), 1090–1098. https://doi.org/10.3758/BF03196742

Reichle, E. D. (2021). *Computational models of reading: A handbook*. Oxford, UK: Oxford University Press.

Reichle, E. D., Pollatsek, A., & Rayner, K. (2012). Using E-Z Reader to simulate eye movements in nonreading tasks: A unified framework for understanding the eye–mind link. *Psychological Review*, *119*(1), 155–185. https://doi.org/10.1037/a0026473

Reichle, E. D., & Yu, L. (2018). Models of Chinese reading: Review and analysis. *Cognitive Science*, *42*, 1154–1165. https://doi.org/10.1111/cogs.12564

Reichle, E. D., & Yu, L. (2024). *The psychology of reading: insights from Chinese*. Cambridge University Press (CUP). https://doi.org/10.1017/9781009272780

Seidenberg, M. S., & McClelland, J. L. (1989). A distributed, developmental model of word recognition and naming. *Psychological Review*, *96*(4), 523–568. https://doi.org/10.1037/0033-295x.96.4.523

Semenza, C., & Luzzatti, C. (2014). Combining words in the brain: The processing of compound words. Introduction to the special issue. *Cognitive Neuropsychology*, *31*(1–2), 1–7. https://doi.org/10.1080/02643294.2014.898922

Shamseer, L., Moher, D., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., Shekelle, P., Stewart, L. A., & the PRISMA-P Group. (2015). Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: Elaboration and explanation. *BMJ (Clinical research ed.)*, *350*, g7647. https://doi.org/10.1136/bmj.g7647

*Shen, W., Li, X., & Pollatsek, A. (2018). The processing of Chinese compound words with ambiguous morphemes in sentence context. *Quarterly Journal of Experimental Psychology*, *71*(1), 131–139. https://doi.org/10.1080/17470218.2016.1270975

Simonsohn, U., Nelson, L. D., & Simmons, J. P. (2014). P-curve: A key to the file-drawer. *Journal of Experimental Psychology: General, 143*(2), 534–547. https://doi.org/10.1037/a0033242

Sze, W. P., Rickard Liow, S. J., & Yap, M. J. (2014). The Chinese Lexicon Project: A repository of lexical decision behavioral responses for 2,500 Chinese characters.

Behavior Research Methods, *46*(1), 263–273. https://doi.org/10.3758/s13428-013-0355-9

Taft, M., & Forster, K. I. (1975). Lexical storage and retrieval of prefixed words. *Journal of Verbal Learning and Verbal Behavior*, *14*(6), 638–647. https://doi.org/10.1016/S0022-5371(75)80051-X

Taft, M., & Forster, K. I. (1976). Lexical storage and retrieval of polymorphemic and polysyllabic words. *Journal of Verbal Learning and Verbal Behavior*, *15*(6), 607–620. https://doi.org/10.1016/0022-5371(76)90054-2

Taft, M., Huang, J., & Zhu, X. (1994). The influence of character frequency on word recognition responses in Chinese. In H. W. Chang, J. T. Hung, C. W. Hue, & O. Tzeng (Eds.), *Advances in the study of Chinese language processing* (pp. 59–73). Taipei: National Taiwan University.

Taft, M., & Nguyen-Hoan, M. (2010). A sticky stick? The locus of morphological representation in the lexicon. *Language and Cognitive Processes*, *25*(2), 277–296. https://doi.org/10.1080/01690960903043261

Taft, M., & Zhu, X. P. (1997). Submorphemic processing in reading Chinese. *Journal of Experimental Psychology: Learning Memory and Cognition*, *23*(3), 761–775. https://doi.org/10.1037/0278-7393.23.3.761

Taft, M., Zhu, X., & Peng, D. (1999). Positional specificity of radicals in Chinese character recognition. *Journal of Memory and Language*, *40*(4), 498–519. https://doi.org/10.1006/jmla.1998.2625

*Tan, L., & Perfetti, C. A. (1999). Phonological activation in visual identification of Chinese two-character words. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *25*(2), 382–393.

*Tan, L., & Peng, D. (1991). Visual recognition processes of Chinese characters: A research to the effect of grapheme and phoneme. *Acta Psychologica Sinica*, *03*, 272–278.

*Tian, H., Yan, G., & Bai, X. (2009). The access representation of Chinese two-character words in mental lexicon. *Journal of Psychological Science*, *32*(6), 1302–1305. https://doi.org/10.16719/j.cnki.1671-6981.2009.06.048

*Tsai, J.-L., Kliegl, R., & Yan, M. (2012). Parafoveal semantic information extraction in traditional Chinese reading. *Acta Psychologica*, *141*(1), 17–23. https://doi.org/10.1016/j.actpsy.2012.06.004

*Tsai, J.-L., Lee, C.-Y., Lin, Y.-C., Tzeng, O. J. L., & Hung, D. L. (2006). Neighborhood size effects of Chinese words in lexical decision and reading. *Language and Linguistics*, *7*(3), 659–675.

*Tsang, Y.-K. (2021). Morphophonological activation in Chinese word recognition: Evidence from heteronymic characters. *The Mental Lexicon*, *16*(2–3), 240–270. https://doi.org/10.1075/ml.21003.tsa

*Tsang, Y.-K., & Chen, H.-C. (2013). Morpho-semantic processing in word recognition: Evidence from balanced and biased ambiguous morphemes. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *39*(6), 1990–2001. https://doi.org/10.1037/a0033701

*Tsang, Y.-K., & Chen, H.-C. (2014). Activation of morphemic meanings in processing opaque words. *Psychonomic Bulletin & Review*, *21*(5), 1281–1286. https://doi.org/10.3758/s13423-014-0589-2

*Tsang, Y.-K., Wong, A. W.-K., Huang, J., & Chen, H.-C. (2014). Morpho-orthographic and morpho-semantic processing in word recognition and production: Evidence from ambiguous morphemes. *Language, Cognition and Neuroscience*, *29*(5), 543–560. https://doi.org/10.1080/01690965.2013.790554

Tsang, Y.-K., & Zou, Y. (2022). An ERP megastudy of Chinese word recognition. *Psychophysiology*. https://doi.org/10.1111/psyp.14111

Tsang, Y.-K., Zou, Y., & Tse, C.-Y. (2022). Semantic transparency in Chinese compound word processing: Evidence from mismatch negativity. *Neuroscience*, *490*, 216–223. https://doi.org/10.1016/j.neuroscience.2022.03.007

Tse, C.-S., Chan, Y.-L., Yap, M. J., & Tsang, H. C. (2022). The Chinese Lexicon Project II: A megastudy of speeded naming performance for 25,000+ traditional Chinese two-character words. *Behavior Research Methods*, *55*(8), 4382–4402. https://doi.org/10.3758/s13428-022-02022-z

Tse, C.-S., & Yap, M. J. (2018). The role of lexical variables in the visual recognition of two-character Chinese compound words: A megastudy analysis. *Quarterly Journal of Experimental Psychology*, *71*(9), 2022–2038. https://doi.org/10.1177/1747021817738965

van Aert, R. C., Wicherts, J. M., & van Assen, M. A. (2016). Conducting Meta-Analyses Based on p Values: Reservations and Recommendations for Applying p-Uniform and p-Curve. *Perspectives on psychological science*, *11*(5), 713–729. https://doi.org/10.1177/1745691616650874

Viechtbauer, W. (2010). Conducting meta-analyses in R with the metafor package. *Journal of Statistical Software, 36*(3), 1–48. https://doi.org/10 .18637/jss.v036.i03

*Wang, C., & Peng, D. (1999). The roles of surface frequencies, cumulative morpheme frequencies, and semantic transparencies in the processing of compound words. *Acta Psychologica Sinica*, *31*(3), 266–273.

*Wang, J., Yang, J., Biemann, C., & Li, X. (2023). Insight to mechanism of semantic processing of lexicalized and novel compound words: An eye movement study. *Journal of Experimental Psychology: Learning, Memory and Cognition.*

*Wang, W., Lu, A., He, D., Zhang, B., & Zhang, J. X. (2017). ERP evidence for Chinese compound word recognition: Does morpheme work all the time? *NeuroQuantology*, *15*(3). https://doi.org/10.14704/nq.2017.15.3.1105

*Wang, Y., & He, L. (2022). The effect of frequency of two-character word and the frequency of the second character on selection of saccade target in older readers during Chinese reading. *Journal of Tianjin Normal University (Social Sciences)*, *3*, 114–120.

*Wang, Y., He, L., Li, X., & Bai, X. (2022). The role of the first character frequency in low-frequency two-character words in parafoveal processing in Chinese reading. *Studies of Psychology and Behavior*, *20*(3), 311–317. https://doi.org/10.12139/j.1672-0628.2022.03.004

*Wang, Y., Jiang, M., Huang, Y., & Qiu, P. (2021). An ERP study on the role of phonological processing in reading two-character compound Chinese words of high and low frequency. *Frontiers in Psychology*, *12*, 637238. https://doi.org/10.3389/fpsyg.2021.637238

*Wang, Y., Li, Z., Jiang, M., Long, F., Huang, Y., & Xu, X. (2024). Time course of Chinese compound word recognition as revealed by ERP data. *Language, Cognition and Neuroscience*, *39*(1), 55–75. https://doi.org/10.1080/23273798.2023.2245074

*Wei, Y., Niu, Y., Taft, M., & Carreiras, M. (2023). Morphological decomposition in Chinese compound word recognition: Electrophysiological evidence. *Brain and Language*, *241*, 105267. https://doi.org/10.1016/j.bandl.2023.105267

*Wong, A. W.-K., Wu, Y., & Chew, H.-C. (2014). Limited role of phonology in reading Chinese two-character compounds: Evidence from an ERP study. *Neuroscience*, *256*, 342–351. https://doi.org/10.1016/j.neuroscience.2013.10.035

*Wu J., Chang J., Qiu Y., & Jo S. (2020). The temporal process of visual word recognition of Chinese compound: Behavioral and ERP evidences based on homographic morphemes. *Acta Psychologica Sinica*, *52*(2), 113–127. https://doi.org/10.3724/SP.J.1041.2020.00113

*Wu, Q. (2013). *The effect of word predictability on positional information process of Chinese word morpheme* [Master degree]. Liaoning Normal University.

*Wu, Y., Duan, R., Zhao, S., & Tsang, Y.-K. (2020). Processing ambiguous morphemes in Chinese compound word recognition: Behavioral and ERP evidence. *Neuroscience*, *446*, 249–260. https://doi.org/10.1016/j.neuroscience.2020.08.006

*Wu, Y., & Li, T. (2018). Morpho-semantic processing during word recognition among third and fifth grade Chinese children. *Journal of Psychological Science*, *41*(3), 572–578. https://doi.org/10.16719/j.cnki.1671-6981.20180310

*Wu, Y., Tsang, Y.-K., Wong, A. W.-K., & Chen, H.-C. (2017). The processing of homographic morphemes in Chinese: An ERP study. *Language, Cognition and Neuroscience*, *32*(1), 102–116. https://doi.org/10.1080/23273798.2016.1227857

Xing, H., Shu, H., & Li, P. (2002). A self-organizing connectionist model of character acquisition in Chinese. *Proceedings of the Twenty-Fourth Annual Conference of the Cognitive Science Society*, *24*, 950–955. https://doi.org/10.4324/9781315782379-198

Xing, H., Shu, H., & Li, P. (2004). The acquisition of Chinese characters: Corpus analyses and connectionist simulations. *Journal of Cognitive Science*, *5*(1), 1–49.

*Xiong, J., Yu, L., Veldre, A., Reichle, E. D., & Andrews, S. (2023). A multitask comparison of word- and character-frequency effects in Chinese reading. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *49*(5), 793–811. https://doi.org/10.1037/xlm0001192

*Xiong, J., Zhang, Y., & Ju, P. (2021). The effects of orthographic neighborhood size and the influence of individual differences in linguistic skills during the recognition of Chinese words. *Frontiers in Psychology*, *12*, 727894. https://doi.org/10.3389/fpsyg.2021.727894

*Yan, G., Sun, S., Cui, L., & Bai, X. (2013). Homophone density effect in naming task and sentence reading. *Journal of Psychological Science*, *36*(4), 776–780. https://doi.org/10.16719/j.cnki.1671-6981.2013.04.018

*Yan, G., Tian, H., Bai, X., & Rayner, K. (2006). The effect of word and character frequency on the eye movements of Chinese readers. *British Journal of Psychology*, *97*, 259–268. https://doi.org/10.1348/000712605X70066

*Yan, M., Richter, E. M., Shu, H., & Kliegl, R. (2009). Readers of Chinese extract semantic information from parafoveal words. *Psychonomic Bulletin & Review*, *16*(3), 561–566. https://doi.org/10.3758/PBR.16.3.561

*Yan, M., Zhou, W., Shu, H., & Kliegl, R. (2012). Lexical and sublexical semantic preview benefits in Chinese reading. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *38*(4), 1069–1075. https://doi.org/10.1037/a0026935

*Yang, H., Taikh, A., & Lupker, S. J. (2022). A reexamination of the impact of morphology on transposed character priming effects. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *48*(6), 785–797. https://doi.org/10.1037/xlm0001119

*Yang, H.-M., McConkie, G. W., Inhoff, A. W., & Chen, H.-C. (1999). Reading Chinese: Some basic eye-movement characteristics. In J. Wang (Ed.), *Reading Chinese Script: A Cognitive Analysis* (pp. 207–222). Lawrence Erlbaum Associates Publishers.

Yang, J. (2013). Preview effects of plausibility and character order in reading Chinese transposed words: Evidence from eye movements. *Journal of Research in Reading*, *36*, S18–S34. https://doi.org/10.1111/j.1467-9817.2013.01553.x

Yang, J., Li, P., McCandliss, B. D., Shu, H., & Zevin, J. D. (2006). A “Triangle Model” of Chinese reading. *Proceedings of the Twenty-Fourth Annual Conference of the Cognitive Science Society*, *28*, 912–917. https://api.semanticscholar.org/CorpusID:18107787

Yang, J., McCandliss, B. D., Shu, H., & Zevin, J. D. (2009). Simulating language-specific and language-general effects in a statistical learning model of Chinese reading. *Journal of Memory and Language*, *61*(2), 238–257. https://doi.org/10.1016/j.jml.2009.05.001

Yang, J., Shu, H., McCandliss, B. D., & Zevin, J. D. (2013). Orthographic influences on division of labor in learning to read Chinese and English: Insights from computational modeling. *Bilingualism: Language and Cognition*, *16*(2), 354–366. https://doi.org/10.1017/S1366728912000296

*Yang, J., Staub, A., Li, N., Wang, S., & Rayner, K. (2012). Plausibility effects when reading one- and two-character words in Chinese: Evidence from eye movements. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *38*(6), 1801–1809. https://doi.org/10.1037/a0028478

*Yao, P., Staub, A., & Li, X. (2022). Predictability eliminates neighborhood effects during Chinese sentence reading. *Psychonomic Bulletin & Review*, *29*(1), 243–252. https://doi.org/10.3758/s13423-021-01966-1

*Yen, M.-H., Radach, R., Tzeng, O. J.-L., & Tsai, J.-L. (2012). Usage of statistical cues for word boundary in reading Chinese sentences. *Reading and Writing*, *25*(5), 1007–1029. https://doi.org/10.1007/s11145-011-9321-z

*Yen, M.-H., Tsai, J.-L., Tzeng, O. J.-L., & Hung, D. L. (2008). Eye movements and parafoveal word processing in reading Chinese. *Memory & Cognition*, *36*(5), 1033–1045. https://doi.org/10.3758/MC.36.5.1033

*Yu, L. (2006). *Interaction between semantic representation of morphemes and words in Chinese two-character words* [Master degree]. Zhejiang University.

*Yu, L., Liu, Y., & Reichle, E. D. (2021). A corpus-based versus experimental examination of word- and character-frequency effects in Chinese reading: Theoretical implications for models of reading. *Journal of Experimental Psychology: General*, *150*(8), 1612–1641. https://doi.org/10.1037/xge0001014

Zang, C., Wang, Y., Bai, X., Yan, G., Drieghe, D., & Liversedge, S. P. (2016). The use of probabilistic lexicality cues for word segmentation in Chinese reading. *Quarterly Journal of Experimental Psychology (2006)*, *69*(3), 548–560. https://doi.org/10.1080/17470218.2015.1061030

*Zhang, B., & Peng, D. (1992). Decomposed storage in the Chinese lexicon. In *Advances in Psychology* (Vol. 90, pp. 131–149). Elsevier. https://doi.org/10.1016/S0166-4115(08)61890-7

*Zhang, J. X., Fang, Z., Du, Y., Kong, L., Zhang, Q., & Xing, Q. (2012). Centro-parietal N200: An event-related potential component specific to Chinese visual word recognition. *Chinese Science Bulletin*, *57*(13), 1516–1532. https://doi.org/10.1007/s11434-011-4932-y

*Zhang, L. (2011). *Representation and access of Chinese compound words* [Doctor degree]. The Chinese University of Hong Kong.

*Zhang, M. (2012). *Immediate and delayed effects of word frequency and word strokes on eye movements in Chinese reading* [Master degree]. Tianjin Normal University.

Zhang, Q., Huang, K.-J., & Li, X. (2024). Competition between parts and whole: A new approach to Chinese compound word processing. *Journal of Experimental Psychology: Human Perception and Performance, 50*(5), 479–497. https://doi.org/10.1037/xhp0001198

*Zhao, B., Wang, Y., Chen, M., Li, X., Yan, G., & Bai, X. (2018). The processing of morpheme and lexical of two-character affects the selection of saccade target during Chinese reading. *Studies of Psychology and Behavior*, *16*(6), 721–734.

*Zhao, S. (2022). *Neural mechanism of morphological processing of ambiguous morphemes in Chinese word recognition: An fMRI study* [Doctor degree]. Northeast Normal University.

*Zhao S., Wu Y., Li T., & Guo Q. (2017). Morpho-semantic processing in Chinese word recognition: An ERP study. *Acta Psychologica Sinica*, *49*(3), 296. https://doi.org/10.3724/SP.J.1041.2017.00296

*Zhao, S., Wu, Y., Tsang, Y.-K., Sui, X., & Zhu, Z. (2021). Morpho-semantic analysis of ambiguous morphemes in Chinese compound word recognition: An fMRI study. *Neuropsychologia*, *157*, 107862. https://doi.org/10.1016/j.neuropsychologia.2021.107862

*Zhou, W., Shu, H., Miller, K., & Yan, M. (2018). Reliance on orthography and phonology in reading of Chinese: A developmental study. *Journal of Research in Reading*, *41*(2), 370–391. https://doi.org/10.1111/1467-9817.12111

Zhou, X., & Marslen-Wilson, W. (2000). Lexical representation of compound words: Cross-linguistic evidence. *Psychologia: An International Journal of Psychology in the Orient*, *43*(1), 47–66.

*Zhou, X., Marslen-Wilson, W., Taft, M., & Shu, H. (1999). Morphology, orthography, and phonology in reading Chinese compound words. *Language and Cognitive Processes*, *14*(5–6), 525–565. https://doi.org/10.1080/016909699386185

Zou, L., Packard, J. L., Xia, Z., Liu, Y., & Shu, H. (2019). Morphological and whole-word semantic processing are distinct: Event related potentials evidence from spoken word recognition in Chinese. *Frontiers in Human Neuroscience*, *13*, 133. https://doi.org/10.3389/fnhum.2019.00133

Table 1

Examples of Experimental Manipulations Used to Study Chinese Compound-Word Identification

Manipulation	Operational Definition	Example for Experimental Condition	Example for Reference Condition	Processing Level
Morpho-orthography (in priming/preview studies)	Does presenting a compound word with a character sharing the visual form (but not meaning) of a character in the target word affect its processing, compared to an unrelated control? Orthographic information of the constituent is pre-activated in experimental condition.	Prime 华侨 (华 means *Chinese* in hua2 qiao2, *overseas Chinese*) - Target 华贵 (华 means *magnificent* in hua2 gui4, *luxurious*)	Prime 完整 (wan2 zheng3, *intact*) - Target 华贵 (hua2 gui4, *luxurious*)	Orthography
Number of strokes	The visual complexity of a character defined by the number of individual strokes required to write a character.	疑 (*suspect*) in 疑虑 (*doubt*) has many strokes (*N* = 14)	心 (*heart*) in 心思 (*mind*) has few strokes (*N* = 4)	Orthography
Homophone density (*HD*)	The number of homophones, i.e., number of characters having an identical pronunciation with identical tone.	The HD of 益 (yi4, *benefit*) in 益智 (means *grow the intellect*) is high (*N* = 42); i.e., other characters such as 异/义/艺 are also pronounced as yi4	The HD of 爽 (shuang3, *crisp*) in 爽快 (means r*efreshed*) is low (*N* = 0)	Phonology
Morpho-phonology (in priming/preview studies)	Does presenting a compound word with a morpheme sharing the phonology (but not visual form or meaning) with a morpheme in the target word affects its processing, compared to an unrelated control? Phonological information of the constituent is pre-activated in experimental condition.	Prime 滑翔 (滑 means *slip* in hua2 xiang2, *glide*) - Target 华贵 (华 means *magnificent* in hua2 gui4, *luxurious*)	Prime 完整 (wan2 zheng3, *intact*) - Target 华贵 (hua2 gui4, l*uxurious*)	Phonology
Number of pronunciations	The total number of different pronunciations that a single character can represent.	The character 成 has only one pronunciation (cheng2)	The character 重 has two pronunciations (zhong4 and chong2), although the comprised compound word has only one pronunciation	Phonology
Morpho-semantics (in priming/preview studies)	Does presenting a compound word with a morpheme sharing the form and meaning with a morpheme in the target word facilitate its processing, compared to a morpheme only sharing the form with the target word? Semantic information of the constituent is pre-activated in experimental condition.	Prime 华丽 (华 means *magnificent* in hua2 li4, *ornate*) - Target 华贵 (华 means *magnificent* in hua2 gui4, *luxurious*)	Prime 华侨 (华 means *Chinese* in hua2 qiao2, *overseas Chinese*) - Target 华贵 hua2 gui4, *luxurious*)	Semantics

Number of meanings	The total number of different meanings that a morpheme has.	The morpheme 花 has multiple meanings related to (a) flowers, as in 花盆 (*flowerpot*); (b) tricks, as in 花招 (*trick*); and (c) spend, as in 花钱 (*expend*)	The morpheme 糖 only has one meaning related to sweet as in 糖水 (*syrup*)	Semantics
Plausibility	Whether the first constituent of a compound word is a plausible head noun when varying the preceding verb.	门 (*door*) in 门卫 (*gate-keeper*) is plausible when paired with the verb 踢打门 (*kick the door)*, and the compound word is also plausible (踢打门卫, *kick the gate-keeper*)	门 (*door*) in 门卫 (*gate-keeper*) is implausible when paired with the verb 哀求门 (*entreat the door*), while the compound word is plausible (哀求门卫, *entreat the gate-keeper)*	Semantics
Semantic transparency	The degree of semantic similarity between morphemes and whole compound word.	家 (*home*) is transparent in 家庭 (*family*) with related meanings	家 (*home*) is opaque in 家伙 (*guy*) without related meanings	Semantics
Morphological priming	Does presenting a compound word that includes a morpheme sharing form and meaning with a target word facilitate its processing, compared to the unrelated control? Orthographic, phonological, and semantic information of the constituent is pre-activated in experimental condition.	Prime 华丽 (华 means *magnificent* in hua2 li4, *ornate*) - Target 华贵 (华 means *magnificent* in hua2 gui4, l*uxurious*)	Prime 完整 (wan2 zheng3, *intact*) - Target 华贵 (hua2 gui4, *luxurious*)	N/A
Character frequency (*CF*)	The number of times a particular character appears within a given corpus of text; e.g., number of occurrences per million words.	The CF of 听 (*listen*) in 听力 (*hearing*) is high (1,741 in SUBTLEX-CH)	The CF of 泥 (*mud*) in 泥塑 (*clay sculpture*) is low (31 in SUBTLEX-CH)	N/A
Contextual diversity (*CD*)	The proportion of texts in a corpus in which a word occurs.	The CD of 手 (*hand*) in 手帕 (*handkerchief*) is high (99% in SUBTLEX-CH)	The CD of 佐 (*aide*) in 佐料 (*condiment*) is low (3.5% in SUBTLEX-CH)	N/A
Neighborhood size (*NS*)	The number of two-character words sharing a constitute character at the same position; similar to *family size* of single character in indicating how many words a character can form at the specific position.	The NS of 大 (*large*) in 大家 (*everyone*) is large (306 in SUBTLEX-CH)	The NS of 邻 (*adjacent*) in 邻居 (*neighbor*) is low (9 in SUBTLEX-CH)	N/A
Position probability	The probability of a character appearing in some position within a compound word, calculated by dividing the number of words where the character appears in a position by the number of two-character words containing that character, regardless of its position.	The position probability of 总 (*total*) in 总部 (*head office*) is high (0.84 in SUBTLEX-CH)	The position probability of 利 (*profit*) in 利益 (*interest*) is low (0.25 in SUBTLEX-CH)	N/A

Morphemic relation priming	The semantic relatedness of two morphemes in a compound word; in priming studies, the prime shares the morpheme and the relation with the target in the experimental condition, but not in the control condition.	Prime 问句 (*sentence indicating question*) - Target 问号 (*mark indicating question*)	Prime 问卷 (*survey papers including questions*) - Target 问号 (*mark indicating question*)	N/A
Morpheme type	Does a character can stand alone as a word?	Experimental condition: 电脑 means *computer* (电 dian4 means *electricity*, 脑 nao3 means *brain*)	蚯蚓 means *earthworm,* with neither 蚯 qiu1 or 蚓 yin3 being a stand-alone word	N/A

Table 2

Moderator Coding Criteria

Moderator (bold) and Level	Coding Criteria
Presentation Method	
In isolation	Target words are presented without prior and subsequent sentence contexts.
In sentences	Target words are presented in sentences, with prior and subsequent contexts (i.e., other words in the sentences).
Paradigm of Isolate-presentation	
Single-word	Each target word is presented on the screen in isolation. Any words that appear before or after are unrelated to the target word.
Priming	A prime word is followed by a target word, with the relation between the two varies across conditions.
Paradigm of Sentence-presentation	
Within-sentence presentation (i.e., natural sentence reading)	The sentence containing the target word is presented normally. Participants read the sentences naturally with their eye-movements recorded.
Preview presentation (i.e., reading with boundary paradigm)	There is an invisible boundary between the target word N and the preceding word N-1. Participants read sentences, with eye-movements recorded. The word N position is presented as a preview word before eyes cross the boundary, and the preview word is replaced by the target word immediately after eyes cross the boundary.
Task in Single-word Paradigm	
Lexical decision	Participants indicate if each stimulus presented on the screen is a word or not by pressing keys.
Naming	Participants rapidly pronounce each word presented on the screen.
Semantic decision	Participants indicate the presence of some semantic feature of a word by pressing keys (e.g., concreteness judgments, category judgments).
Task in Priming Paradigm	
Primed lexical decision	Participants indicate if each target stimulus is a word or not by pressing keys; no response is required for the prime stimulus (except 7 studies[13]).
Primed naming	Participants rapidly pronounce target words; no responses are required to the prime words.
Primed semantic decision	Participants decide whether the target word is semantically related to the prime word by pressing keys.
Manipulation	The independent variable manipulated in studies, which represents a characteristic of the constituent or the relation between prime/preview and target words and is different under experimental and reference conditions as defined in Table 1.
Character frequency	Character frequency of target words manipulated.
Contextual diversity	Contextual diversity of target words manipulated.
Homophone density	Homophone density of target words manipulated.
Morpho-orthography	Morpho-orthographic relatedness of target words manipulated.

[13] Participants responded to all stimuli in these studies, while only the response times for the target words were analyzed. In four studies, prime-target pairs were presented adjacently (Cong, 2019; Jia et al., 2013; Jia & Zhou, 2023); in three studies with long-lag priming, the primes and targets were separated by 8–12 intervening trials (Tsang et al., 2014).

Morpho-phonology	Morpho-phonological relatedness of target words manipulated.
Morpho-semantics	Morpho-semantic relatedness of target words manipulated.
Morphology	Morpho-orthographic, morpho-phonological, and morpho-semantic relatedness of target words manipulated.
Morphemic relation	Semantic relation between two morphemes of target words manipulated.
Morpheme type	Morpheme type of target-word constituents manipulated.
Neighborhood size	Neighborhood size of target words manipulated.
Number of strokes	Visual complexity of target-word constituents manipulated.
Number of meanings	Number of meanings of target-word constituents manipulated.
Number of pronunciations	Number of pronunciations of target-word constituents manipulated.
Plausibility	Plausibility of target-word constituents manipulated.
Position probability	Positional probability of target-word constituents manipulated.
Semantic transparency	Semantic transparency of target-word constituents manipulated.
Compound-word frequency	
Low frequency	Words in the study are explicitly reported as low-frequency.
High frequency	Words in the study are explicitly reported as high-frequency.
Writing system[14]	
Simplified Chinese	Stimuli presented in the study are written in simplified Chinese.
Traditional Chinese	Stimuli presented in the study are written in traditional Chinese.
Publication year	Publication time of a journal article or book, or the submission time of a thesis or dissertation (coded as a continuous variable).
Publication type	
Journal article	Peer-reviewed articles published in journals.
Other types	Theses, dissertations, book chapters

[14] Simplified Chinese is widely used in Mainland China, while traditional Chinese is mainly used in Taiwan, Hong Kong, and Macao. Compared to simplified Chinese, characters written in traditional Chinese tend to be more visually complex.

Table 3

Models of Chinese Compound-Word Identification and Eye-Movement Control in Reading

Models	Explained Tasks	Model Architecture	Key Assumptions
Triangle model (Smith et al., 2021)	Lexical decision, naming, semantic decision	Orthographic level: network of interconnected nodes, containing 50 units Phonological level: similar to the above, containing 50 units Semantic level: similar to the above, containing 150 units	Orthographic, phonological, and semantic processing of whole-words: knowledge is represented in a distributed manner across the networks
Tan & Perfetti's 1999) model	Semantic decision, lexical decision	Orthographic level: constituent and word representations Phonological level: same as above Semantic level: same as above	Orthographic, phonological, and semantic processing of constituents and whole-words (similar processing across all levels) Constituents and whole-words are processed simultaneously and with some degree of independence
Inter/intra connection model (IIC; Peng et al., 1999)	Lexical decision, primed lexical decision	Orthographic level: constituent representations Phonological level: not implemented Semantic level: constituent and whole-word representations	Orthographic processing of constituents: facilitative effects Semantic processing of constituents: facilitative effects on transparent words and inhibitory effects on opaque words
Lemma model[15] (Taft et al., 1999; Taft, 2003; Taft & Nguyen-Hoan, 2010)	Lexical decision, primed lexical decision	Orthographic level: constituent representations Phonological level: constituent representations Semantic level: constituent and whole-word representations	Orthographic and phonological processing of constituents: facilitative effects Semantic processing of constituents: facilitative effects on transparent words, no effects on opaque words
X. L. Zhou and Marslen-Wilson's (2000) model	Primed lexical decision	Orthographic level: constituent representations Phonological level: constituent representations Semantic level: constituent and whole-word representations	Orthographic and phonological processing of constituents: facilitative effects, with the processing of whole-words reflecting their constituents Semantic processing of constituents: facilitative and inhibitory effects (parallel to and competing with whole-word processing)
Chinese Reading Model (CRM; Li & Pollatsek's, 2020)	Sentence reading	Orthographic level: constituent and whole-word representations Phonological level: not implemented Semantic level: not implemented	Orthographic processing of constituents: facilitative effects from character nodes and inhibitory effects (competition) from word nodes (assumes orthographic processing at both sub-levels)
Chinese E-Z Reader (CEZR; Yu et al., 2021)	Sentence reading	Orthographic level: constituent and whole-word representations Phonological level: not implemented Semantic level: not implemented	Orthographic processing of constituents: facilitative effects, with inhibitory effects on (some) words embedded in sentences

[15] The Lemma model (Taft et al., 1999; Taft, 2003; Taft & Nguyen-Hoan, 2010) assumes a lemma level between the form and semantic levels, with both whole words and constituents being represented as lemmas. There is also hierarchical relationship between these two types of lemmas, with the whole-word lemma being activated by the activation of their constituent lemmas. Importantly, the lemmas are neither orthographic nor semantic, but instead represent the correlation between orthography and semantics. Thus, according to the model, orthography and phonology are represented by constituents while the semantic level is represented by both constituents and whole words.

Table 4

Number of Effect Sizes and Studies (in Parenthesis) for Variables Across Tasks

Variable	Level	General	Lexical Decision	Naming	Semantic Decision	Primed Lexical Decision	Primed Naming	Primed Semantic Decision	Natural Reading	Reading, Boundary Paradigm
Publication Type	Journal	223(111)	33(18)	6(5)	2(2)	109(42)	4(2)	2(1)	47(31)	20(10)
	Other	45(28)	8(4)	0	0	21(12)	0	0	16(12)	0
Publication Language	Chinese	73(46)	6(3)	0	0	35(20)	4(2)	0	28(21)	0
	English	195(93)	35(19)	6(5)	2(2)	95(34)	0	2(1)	35(22)	20(10)
Writing System	Simplified	186(101)	19(9)	2(1)	0	87(40)	4(2)	2(1)	57(40)	15(8)
	Traditional	82(38)	22(13)	4(4)	2(2)	43(14)	0	0	6(3)	5(2)
Word Frequency	Low	28(22)	7(6)	1(1)	0	2(2)	0	1(1)	17(12)	0
	High	27(18)	7(6)	1(1)	0	9(3)	0	1(1)	9(7)	0
Presentation Method	In Isolation	185(86)	41(22)	6(5)	2(2)	130(54)	4(2)	2(1)	0	0
	In Sentence	83(53)	0	0	0	0	0	0	63(43)	20(10)
Presentation Paradigm	Single-word	49(29)	41(22)	6(5)	2(2)	0	0	0	0	0
	Priming	136(57)	0	0	0	130(54)	4(2)	2(1)	0	0
	Natural-sentence	63(43)	0	0	0	0	0	0	63(43)	0
	Preview	20(10)	0	0	0	0	0	0	0	20(10)
Processing Level	Orthography	45(30)	0	0	0	33(23)	2(1)	0	6(2)	4(4)
	Phonology	25(20)	2(1)	0	0	12(10)	2(1)	2(1)	1(1)	6(6)
	Semantics	68(51)	10(6)	0	2(2)	41(30)	0	0	5(5)	10(8)
Manipulation	Character Frequency	53(35)	15(9)	5(4)	0	0	0	0	33(22)	0
	Contextual Diversity	2(2)	0	0	0	0	0	0	2(2)	0
	Homophone Density	1(1)	0	0	0	0	0	0	1(1)	0
	Morpho-orthography	39(28)	0	0	0	33(23)	2(1)	0	0	4(4)
	Morpho-phonology	22(18)	0	0	0	12(10)	2(1)	2(1)	0	6(6)
	Morphemic Relation	5(5)	0	0	0	5(5)	0	0	0	0
	Morpho-semantics	47(34)	0	0	0	37(26)	0	0	0	10(8)
	Morpheme Type	3(2)	2(1)	0	0	1(1)	0	0	0	0
	Morphology	38(27)	0	0	0	38(27)	0	0	0	0

Neighborhood Size	12(8)	8(5)	1(1)	0	0	0	0	3(2)	0
Number of Meanings	8(4)	7(3)	0	1(1)	0	0	0	0	0
Number of Pronunciations	2(1)	2(1)	0	0	0	0	0	0	0
Plausibility	2(2)	0	0	0	0	0	0	2(2)	0
Position Probability	17(13)	4(2)	0	0	0	0	0	13(11)	0
Number of Strokes	6(2)	0	0	0	0	0	0	6(2)	0
Semantic Transparency	11(11)	3(3)	0	1(1)	4(4)	0	0	3(3)	0

Table 5

Effect Size Estimates for Each Subgroup of Moderators

Moderator (bolded) and levels	s	k	g_{rm}	95% CI	b(SE)	$R^2_{(2)}$	$R^2_{(3)}$	p
Presentation Method	139	268				.053	.224	<.001
Presented in isolation (RC)	86	185	0.25	[0.21, 0.29]				<.001
Presented in sentences	53	83	0.13	[0.07, 0.19]	-0.12 (0.04)			<.001
Paradigm of isolated presentation	86	185				.012	.199	.114
Single Word	29	49	0.20	[0.12, 0.28]				<.001
Priming	57	136	0.28	[0.23, 0.33]	0.08 (0.05)			<.001
Paradigm of sentence presentation	53	83				.046	.215	.038
Natural reading (RC)	43	63	0.10	[0.04, 0.16]				.001
Reading with a Boundary	10	20	0.23	[0.12, 0.33]	0.13 (0.06)			<.001
Task for single-word presentation	27	47				.048	.267	.087
Lexical Decision (RC)	22	41	0.17	[0.05, 0.29]				.006
Naming	5	6	0.45	[0.15, 0.76]	0.28 (0.16)			.004
Manipulation in Lexical Decision Task	14	23				.000	.000	.769
Character frequency (RC)	9	15	0.18	[-0.08, 0.43]				.170
Neighborhood size	5	8	0.11	[-0.24, 0.46]	-0.06 (0.21)			.507
Manipulation in Primed Lexical Decision Task	53	129				.304	.000	<.001
Morpho-orthographic Priming (RC)	23	33	0.26	[0.17, 0.34]				<.001
Morpho-phonological Priming	10	12	0.08	[-0.06, 0.22]	-0.18 (0.08)			.247
Morpho-semantic Priming	26	37	0.24	[0.16, 0.32]	-0.02 (0.06)			<.001
Morphological Priming	27	38	0.41	[0.33, 0.50]	0.16 (0.06)			<.001
Morphemic relation Priming	5	5	0.37	[0.14, 0.59]	0.11 (0.12)			.001
Transparency	4	4	0.11	[-0.13, 0.34]	-0.15 (0.13)			.379
Manipulation in Natural Reading Task	35	52				.012	.038	.212
Character frequency (RC)	22	33	0.02	[-0.04, 0.08]				.551
Position Probability	11	13	0.08	[-0.01, 0.18]	0.06 (0.06)			.065
Number of Strokes	2	6	0.18	[-0.02, 0.38]	0.16 (0.10)			.078

Manipulation in Reading with a Boundary	10	20				.000	.024	.324
Morpho-orthographic Preview (RC)	4	4	0.37	[0.14, 0.60]				.004
Morpho-phonological Preview	6	6	0.17	[-0.01, 0.36]	-0.20 (0.13)			.065
Morpho-semantic Preview	8	10	0.21	[0.06, 0.37]	-0.16 (0.12)			.009
Word Frequency	27	55				.000	.000	.613
Low (RC)	22	28	0.04	[-0.03, 0.12]				.251
High	19	27	0.07	[-0.01, 0.15]	0.03 (0.05)			.068
Writing System	139	268				.012	.266	.112
Simplified (RC)	101	186	0.20	[0.16, 0.24]				<.001
Traditional	38	82	0.26	[0.20, 0.32]	0.06 (0.04)			<.001
Publication Type	139	268				.000	.000	.722
Journal (RC)	111	223	0.22	[0.18, 0.26]				<.001
Other	28	45	0.20	[0.12, 0.29]	-0.02 (0.05)			<.001

Notes:
s = number of studies; *k* = number of effect size estimates; g_{rm} = Hedges' g; 95% CI corresponds to the 95% confidence intervals of the g_{rm} values for individual levels of moderators; $R^2_{(2)}$ and $R^2_{(3)}$ represent variance explained at Levels 2 and 3, respectively; *p* corresponds to the significance level of the effect size.

Table 6

Effect size estimates for processing levels and manipulations

Variable	Manipulation (bolded) and Task	s	k	g_{rm}	95% CI	*p*
Orthographic Processing	**Morpho-orthographic Priming/Preview**	27	37	0.28	[0.20, 0.37]	<.001
	Primed Lexical Decision	23	33	0.26	[0.17, 0.35]	<.001
	Reading, Boundary Paradigm	4	4	0.37	[0.12, 0.62]	.005
	Position Probability	13	17	0.09	[-0.03, 0.21]	.124
	Lexical Decision	2	4	0.14	[-0.01, 0.28]	.066
	Natural Reading	11	13	0.08	[0.00, 0.16]	.061
	Number of Strokes	2	6	0.21	[-0.02, 0.44]	.070
Phonological Processing	**Morpho-phonological Priming/Preview**	16	18	0.14	[0.03, 0.25]	.013
	Primed Lexical Decision	10	12	0.11	[-0.05, 0.27]	.152
	Reading with a Boundary	6	6	0.16	[-0.04, 0.37]	.103
Semantic Processing	**Morpho-semantic Priming/Preview**	34	47	0.22	[0.14, 0.29]	<.001
	Primed Lexical Decision	26	37	0.22	[0.15, 0.30]	<.001
	Reading with a Boundary	8	10	0.20	[0.08, 0.33]	.003
	Number of Meanings	4	8	0.11	[-0.08, 0.30]	.262
	Transparency	11	11	0.20	[0.05, 0.36]	.011
Other Manipulations	**Character Frequency**	35	53	0.10	[0.03, 0.17]	.006
	Lexical Decision	9	15	0.14	[-0.05, 0.32]	.153
	Naming	4	5	0.41	[0.11, 0.70]	.008
	Natural Reading	22	33	0.02	[-0.10, 0.14]	.741
	Neighborhood Size	8	12	0.25	[0.10, 0.40]	.001
	Morphology Priming	27	38	0.40	[0.31, 0.48]	<.001
	Morphemic Relation Priming	5	5	0.37	[0.13, 0.60]	.003

Notes:
s = number of studies; *k* = number of effect size estimates; g_{rm} = Hedges' g; 95% CI corresponds to the 95% confidence intervals of the g_{rm} values for individual levels of moderators; *p* corresponds to the significance level of the effect size.

Figure 1

Flowchart Illustrating the Study Screening and Selection Process

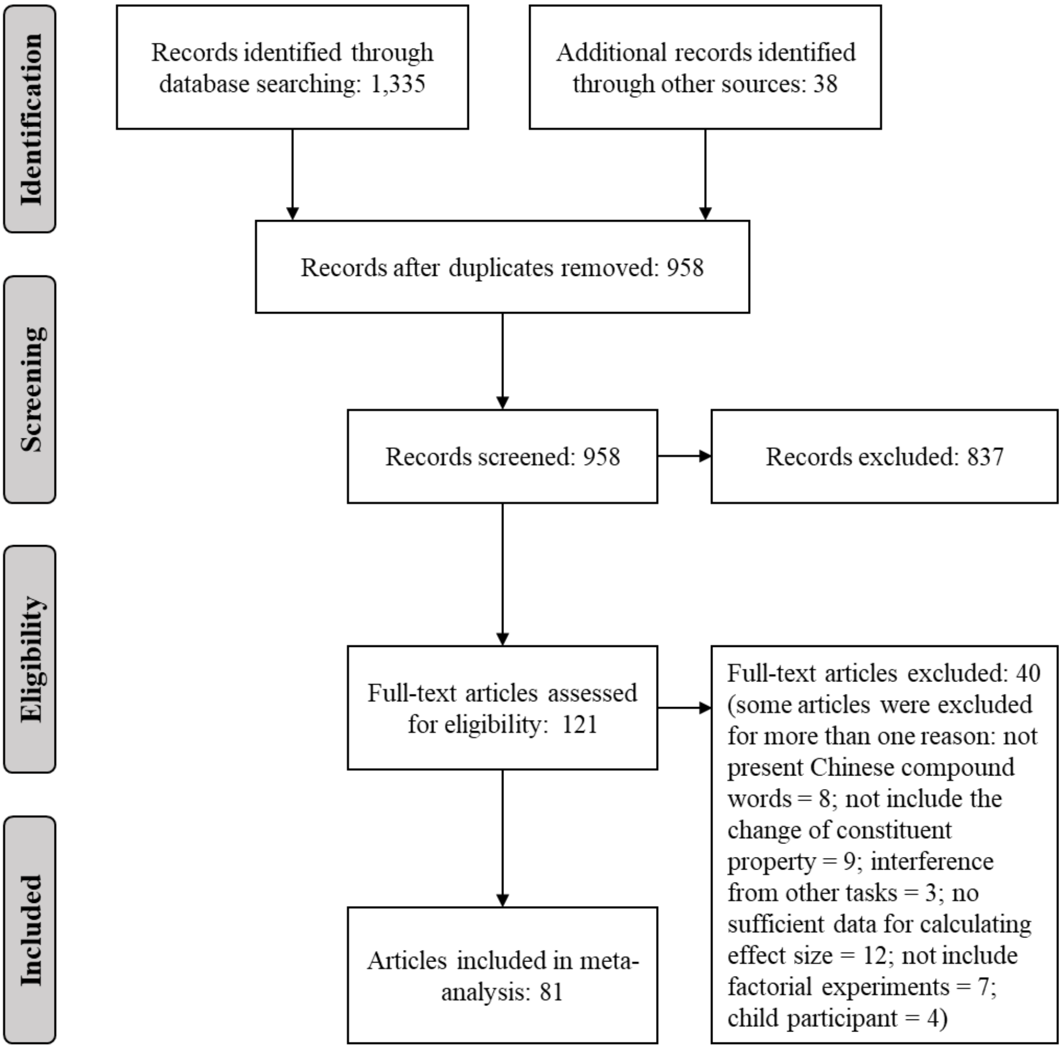
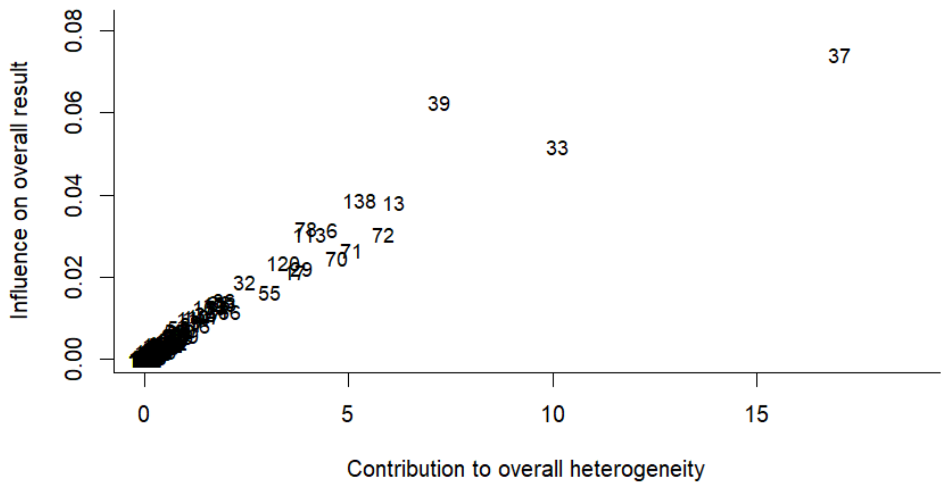


Figure 2

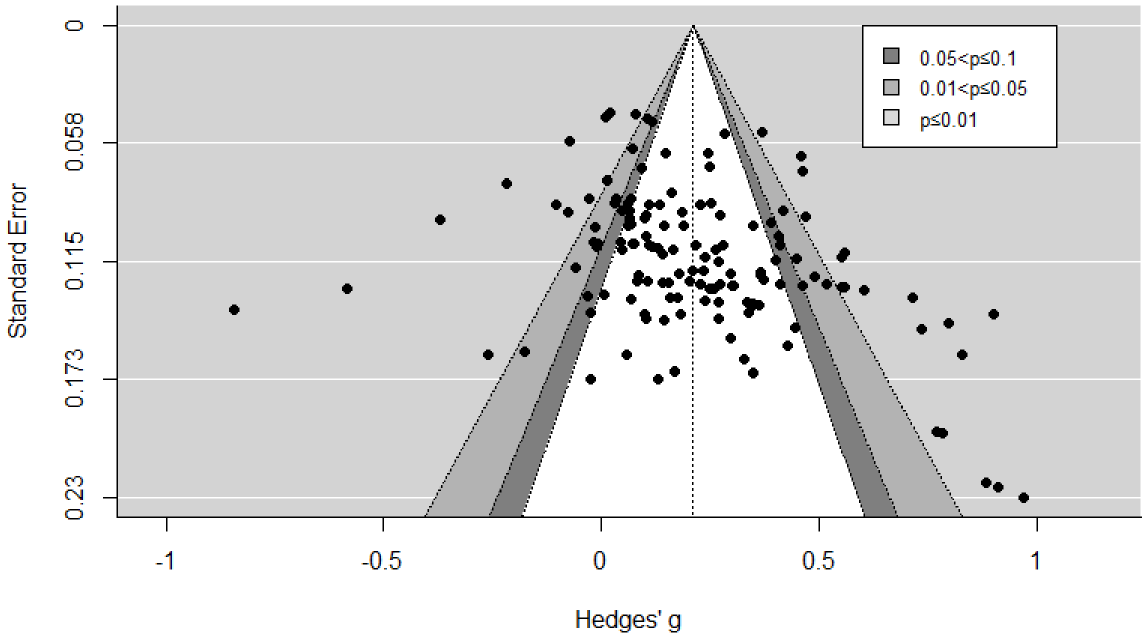
Baujat plot of studies examining the constituent effects



Note. The plot shows the contribution of each effect size to the overall heterogeneity on the horizontal axis, and its influence on the overall effect size on the vertical axis. The numbers indicate effect sizes included in the meta-analysis. The three effect sizes that contributed the most to the overall heterogeneity (i.e., 33, 37, 39) were from three different studies (Huang, C.-Y et al., 2011; Huang, H.-W & Lee, 2018; Huang, H.-W et al., 2006).

Figure 3

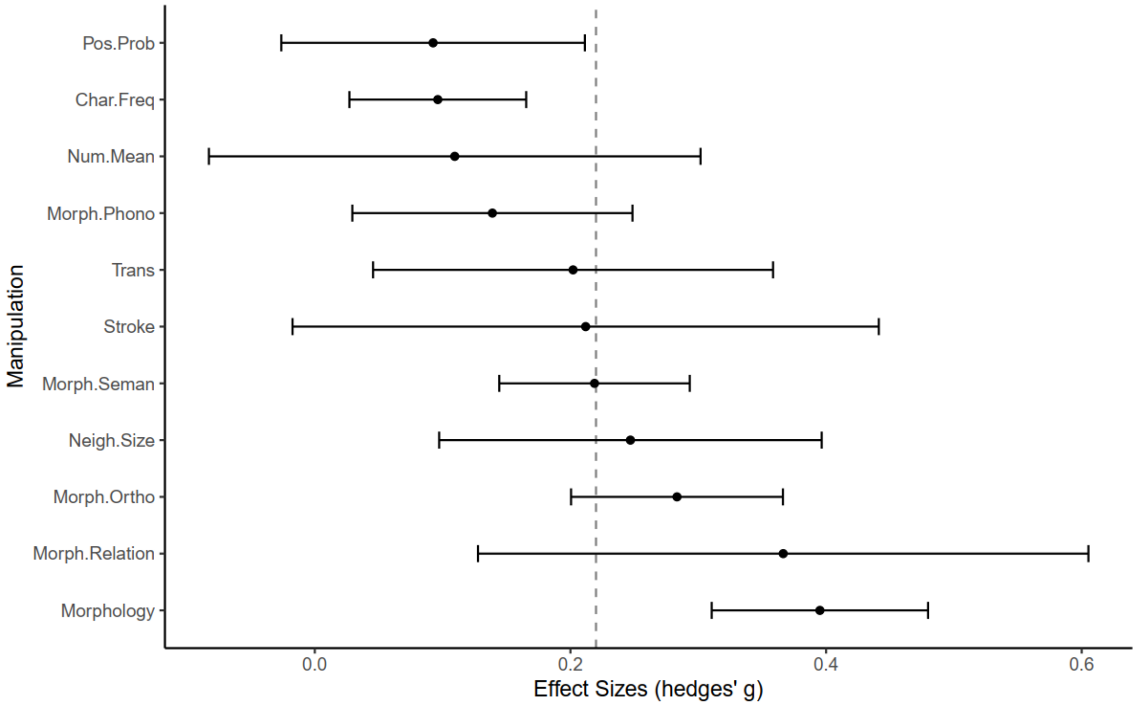
Overall funnel plot for studies examining the constituent effects



Note. The dots represent studies included in meta-analysis.

Figure 4

Manipulation-Level Mean Effect Sizes



Note. Pos.Prob = position probability, Char.Freq = character frequency, Num.Mean = number of meanings, Morph.Phono = morpho-phonology, Trans = semantic transparency, Stroke = number of strokes, Morph.Seman = morpho-semantics, Neigh.Size = neighborhood size, Morph.Ortho = morpho-orthography, Morph.Relation = morphemic relation priming, Morphology = morphological priming; operational definition and examples of different manipulations can be found in Table 1.

Appendix A

Table A1

Description of Studies in Meta-Analysis of Constituent Effect

Authors	Experi-ment	Publica-tion Year	Sample N	Age	*r*	Cohens *d*	Word Freq-uency	Process-ing Level	Manipu-lation	Writing System	Present-ation Method	Paradigm	Task	Publication Language	Publication Type	Set Size	DV	yi	vi
Cao et al.	1a	2023	60	19.7	0.71	-0.05	2	1	Pos.Prob	1	1	1	LD	1	1	40	RT	-0.05	0.01
Cao et al.	1b	2023	60	19.7	0.71	0.12	2	1	Pos.Prob	1	1	1	LD	1	1	40	RT	0.12	0.01
Cao et al.	2a	2023	60	19.7	0.71	0.51	1	1	Pos.Prob	1	1	1	LD	1	1	40	RT	0.51	0.01
Cao et al.	2b	2023	60	19.7	0.71	0.00	1	1	Pos.Prob	1	1	1	LD	1	1	40	RT	0.00	0.01
Cao et al.	3a	2023	60	19.7	0.71	-0.04	2	1	Pos.Prob	1	2	3	Reading	1	1	48	GD	-0.04	0.01
Cao et al.	3b	2023	60	19.7	0.71	-0.02	2	1	Pos.Prob	1	2	3	Reading	1	1	48	GD	-0.02	0.01
Cao et al.	4a	2023	60	19.7	0.71	0.20	1	1	Pos.Prob	1	2	3	Reading	1	1	64	GD	0.20	0.01
Cao et al.	4b	2023	60	19.7	0.71	-0.06	1	1	Pos.Prob	1	2	3	Reading	1	1	64	GD	-0.06	0.01
Chen, L., Xu et al.	1a	2023	26	19.7	0.71	0.77	NA	4	Morphology	1	1	2	PrimedLD	2	1	58	RT	0.75	0.03
Chen, L., Xu et al.	1b	2023	26	19.7	0.71	-0.09	NA	3	Trans	1	1	2	PrimedLD	2	1	58	RT	-0.08	0.02
Chen, L., Xu et al.	2a	2023	33	19.5	0.71	1.70	NA	4	Morphology	1	1	2	PrimedLD	2	1	58	RT	1.66	0.04
Chen, L., Xu et al.	2b	2023	33	19.5	0.71	-0.07	NA	3	Trans	1	1	2	PrimedLD	2	1	58	RT	-0.07	0.02
Chen, Q. et al.	1a	2017	30	NA	0.71	-0.19	NA	NA	Char.Freq	1	2	3	Reading	2	1	27	GD	-0.19	0.02
Chen, Q. et al.	1b	2017	30	NA	0.71	0.81	NA	NA	Cont.Divers	1	2	3	Reading	2	1	27	GD	0.79	0.02
Chen, Q. et al.	2a	2017	48	NA	0.71	-0.07	NA	NA	Char.Freq	1	2	3	Reading	2	1	16	GD	-0.07	0.01
Chen, Q. et al.	2b	2017	48	NA	0.71	0.89	NA	NA	Cont.Divers	1	2	3	Reading	2	1	16	GD	0.88	0.02
Cong	1	2019	42	NA	0.71	0.50	NA	NA	Morph.Relation	1	1	2	PrimedLD	1	2	16	RT	0.49	0.01
Cong	2	2019	48	NA	0.71	0.46	NA	NA	Morph.Relation	1	1	2	PrimedLD	1	2	12	RT	0.45	0.01
Cui et al.	1a	2021	48	NA	0.71	0.08	2	NA	Char.Freq	1	2	3	Reading	2	1	20	GD	0.08	0.01
Cui et al.	1b	2021	48	NA	0.71	0.05	2	NA	Char.Freq	1	2	3	Reading	2	1	20	GD	0.05	0.01
Cui et al.	2a	2021	44	NA	0.71	-0.11	1	NA	Char.Freq	1	2	3	Reading	2	1	15	GD	-0.11	0.01
Cui et al.	2b	2021	44	NA	0.71	0.08	1	NA	Char.Freq	1	2	3	Reading	2	1	15	GD	0.08	0.01
Cui et al.	1	2013	68	NA	0.71	-0.37	1	NA	Char.Freq	1	2	3	Reading	2	1	16	GD	-0.37	0.01
Ding & Peng	1a	2006	120	NA	0.71	0.22	NA	1	Morph.Ortho	1	1	2	PrimedN	1	1	14	RT	0.22	0.00

Ding & Peng	1b	2006	120	NA	0.71	0.71	NA	1	Morph.Ortho	1	1	2	PrimedN	1	1	14	RT	0.70	0.01
Du, Y.	1	2021	28	20.0	0.71	0.28	NA	3	Trans	1	2	3	Reading	1	2	40	GD	0.27	0.02
Du, Y.	2	2021	38	20.0	0.71	0.09	NA	3	Trans	1	2	3	Reading	1	2	20	GD	0.08	0.01
Gao, F. et al.	1	2021	18	NA	0.71	0.81	NA	4	Morphology	1	1	2	PrimedLD	2	1	30	RT	0.77	0.04
Gao, Q	1	2018	61	22.0	0.71	0.07	NA	1	Pos.Prob	1	2	3	Reading	1	2	45	GD	0.07	0.01
Gao, Q	2	2018	61	22.0	0.71	0.19	NA	1	Pos.Prob	1	2	3	Reading	1	2	45	GD	0.19	0.01
Han et al.	1	2014	32	NA	0.71	0.18	NA	3	Trans	2	1	1	LD	2	1	46	RT	0.18	0.02
Han et al.	2	2014	32	NA	0.71	-0.03	NA	3	Trans	2	1	1	SD	2	1	46	RT	-0.03	0.02
Huang, C. et al.	1	2011	18	22.6	0.71	0.14	NA	3	Num.Mean	2	1	1	LD	2	1	30	RT	0.13	0.03
Huang, C. et al.	2	2011	28	22.4	0.71	0.10	NA	3	Num.Mean	2	1	1	SD	2	1	30	RT	0.10	0.02
Huang, H. & Lee	1a	2018	25	22.1	0.71	-0.29	NA	3	Num.Mean	2	1	1	LD	2	1	30	RT	-0.28	0.02
Huang, H. & Lee	1b	2018	25	22.1	0.71	0.07	NA	3	Num.Mean	2	1	1	LD	2	1	30	RT	0.07	0.02
Huang, H. & Lee	1c	2018	25	22.1	0.71	0.29	NA	3	Num.Mean	2	1	1	LD	2	1	30	RT	0.29	0.02
Huang, H. & Lee	1d	2018	25	22.1	0.71	0.67	NA	3	Num.Mean	2	1	1	LD	2	1	30	RT	0.64	0.03
Huang, H. et al.	1a	2006	40	22.6	0.71	0.58	2	NA	Neigh.Size	2	1	1	LD	2	1	30	RT	0.57	0.02
Huang, H. et al.	1b	2006	40	22.6	0.71	-0.49	1	NA	Neigh.Size	2	1	1	LD	2	1	30	RT	-0.48	0.02
Huang, H. et al.	1a	2011	21	21.9	0.71	0.18	2	3	Num.Mean	2	1	1	LD	2	1	30	RT	0.18	0.03
Huang, H. et al.	1b	2011	21	21.9	0.71	-0.23	1	3	Num.Mean	2	1	1	LD	2	1	30	RT	-0.22	0.03
Hyönä et al.	1a	2024	56	NA	0.78	0.05	1	NA	Char.Freq	1	2	3	Reading	2	1	10	GD	0.05	0.01
Hyönä et al.	1b	2024	56	NA	0.78	-0.02	1	NA	Char.Freq	1	2	3	Reading	2	1	10	GD	-0.02	0.01
Hyönä et al.	2a	2024	50	NA	0.71	0.13	1	NA	Char.Freq	1	2	3	Reading	2	1	10	GD	0.13	0.01
Hyönä et al.	2b	2024	50	NA	0.71	0.08	1	NA	Char.Freq	1	2	3	Reading	2	1	10	GD	0.08	0.01
Jia, Wang, S. et al.	1	2013	18	21.3	0.71	0.82	1	NA	Morph.Relation	1	1	2	PrimedLD	2	1	66	RT	0.78	0.04
Jia & Zhou, C.	1	2023	27	22.7	0.71	0.10	NA	NA	Morph.Relation	1	1	2	PrimedLD	2	2	36	RT	0.10	0.02
Lee et al.	1a	2021	24	22.5	0.71	0.56	NA	NA	Neigh.Size	2	1	1	LD	2	1	96	RT	0.54	0.03
Lee et al.	1b	2021	24	22.5	0.71	-0.53	NA	NA	Neigh.Size	2	1	1	LD	2	1	96	RT	-0.51	0.03
Lee et al.	1c	2021	24	22.5	0.71	0.80	NA	3	Trans	2	1	1	LD	2	1	96	RT	0.77	0.03
Li, Mengfei et al.	1	2017	40	20.3	0.71	0.61	NA	NA	Char.Freq	2	1	1	Naming	2	1	56	RT	0.60	0.02
Li, Mengfei et al.	2	2017	40	21.1	0.71	-0.60	NA	NA	Char.Freq	2	1	1	LD	2	1	56	RT	-0.59	0.02
Li, Mengfei et al.	3	2017	40	21.2	0.71	0.53	NA	NA	Char.Freq	2	1	1	Naming	2	1	26	RT	0.52	0.02
Li, Mengfei et al.	4	2017	40	20.4	0.71	0.53	NA	NA	Char.Freq	2	1	1	LD	2	1	26	RT	0.52	0.02
Li, Mengfei et al.	5	2017	40	20.5	0.71	0.56	NA	NA	Char.Freq	2	1	1	Naming	2	1	26	RT	0.55	0.02
Li, Mengfei et al.	6	2017	40	21.7	0.71	-0.86	NA	NA	Char.Freq	2	1	1	LD	2	1	26	RT	-0.84	0.02

Li, Mengfei et al.	1	2015	40	20.7	0.71	0.30	NA	NA	Neigh.Size	2	1	1	LD	2	1	50	RT	0.30	0.01
Li, Mengfei et al.	2	2015	40	21.0	0.71	0.92	NA	NA	Neigh.Size	2	1	1	Naming	2	1	50	RT	0.90	0.02
Li, Ming	1	2018	48	NA	0.71	0.17	1	NA	Char.Freq	1	2	3	Reading	1	2	15	GD	0.16	0.01
Lian	1	2019	76	19.0	0.71	0.03	NA	1	Pos.Prob	1	2	3	Reading	1	2	22	GD	0.03	0.01
Lian	2	2019	76	19.0	0.71	0.13	NA	1	Pos.Prob	1	2	3	Reading	1	2	22	GD	0.13	0.01
Lian	3	2019	60	18.4	0.71	0.06	NA	1	Pos.Prob	1	2	3	Reading	1	2	11	GD	0.06	0.01
Lian	4	2019	60	18.4	0.71	0.15	NA	1	Pos.Prob	1	2	3	Reading	1	2	11	GD	0.14	0.01
Liang et al.	1	2022	48	22.2	0.72	-0.02	NA	1	Pos.Prob	1	2	3	Reading	2	1	22	GD	-0.02	0.01
Liang et al.	2	2022	48	22.2	0.80	0.19	NA	1	Pos.Prob	1	2	3	Reading	2	1	17	GD	0.19	0.01
Lin et al.	1a	2002	40	NA	0.71	0.10	NA	2	Morph.Phono	1	1	2	PrimedLD	1	1	10	RT	0.10	0.01
Lin et al.	1b	2002	40	NA	0.71	0.11	NA	2	Morph.Phono	1	1	2	PrimedLD	1	1	10	RT	0.10	0.01
Lin et al.	2a	2002	36	NA	0.71	0.26	NA	2	Morph.Phono	1	1	2	PrimedN	1	1	10	RT	0.25	0.02
Lin et al.	2b	2002	36	NA	0.71	0.00	NA	2	Morph.Phono	1	1	2	PrimedN	1	1	10	RT	0.00	0.02
Liu, D. & McBride-Chang	1	2010	21	NA	0.71	0.06	NA	NA	Morph.Relation	2	1	2	PrimedLD	2	1	29	RT	0.06	0.03
Liu. X.	1	2017	28	22.3	0.71	0.46	NA	3	Trans	1	2	3	Reading	1	2	30	GD	0.44	0.02
Liu, Z., Liu, X. et al.	1	2020	286	NA	0.71	0.01	NA	NA	Char.Freq	1	2	3	Reading	2	1	24	GD	0.01	0.00
Liu, Z., Liu, X. et al.	2	2020	282	NA	0.71	0.11	NA	NA	Char.Freq	1	2	3	Reading	2	1	24	GD	0.11	0.00
Liu, Z., Tong, W. et al.	2	2020	318	NA	0.71	0.02	NA	NA	Char.Freq	1	2	3	Reading	1	1	20	GD	0.02	0.00
Liu, Z., Tong, W. et al.	3	2020	314	NA	0.71	0.08	NA	NA	Char.Freq	1	2	3	Reading	1	1	20	GD	0.08	0.00
Ma, G. et al.	1	2015	24	NA	0.68	-0.27	NA	NA	Char.Freq	1	2	3	Reading	2	1	24	GD	-0.26	0.03
Ma, G. et al.	2	2015	30	NA	0.61	-0.18	NA	NA	Char.Freq	1	2	3	Reading	2	1	24	GD	-0.18	0.03
Pan et al.	1a	2016	57	NA	0.71	0.04	NA	2	Morph.Phono	1	2	4	Boundary	2	1	15	GD	0.04	0.01
Pan et al.	1b	2016	57	NA	0.71	-0.25	NA	3	Morph.Seman	1	2	4	Boundary	2	1	15	GD	-0.25	0.01
Pan et al.	2a	2016	57	NA	0.71	0.44	NA	2	Morph.Phono	1	2	4	Boundary	2	1	15	GD	0.43	0.01
Pan et al.	2b	2016	57	NA	0.71	0.41	NA	3	Morph.Seman	1	2	4	Boundary	2	1	15	GD	0.41	0.01
Pan et al.	2	2021	51	NA	0.71	0.28	NA	2	Morph.Phono	1	2	4	Boundary	2	1	26	GD	0.28	0.01
Peng, Ding et al.	1	1999	32	NA	0.71	0.37	NA	4	Morphology	1	1	2	PrimedLD	1	1	16	RT	0.36	0.02
Peng, Ding et al.	2	1999	36	NA	0.71	0.08	NA	4	Morphology	1	1	2	PrimedLD	1	1	16	RT	0.08	0.02
Peng, Ding et al.	3	1999	36	NA	0.71	0.23	NA	4	Morphology	1	1	2	PrimedLD	1	1	16	RT	0.23	0.02
Peng, Ding et al.	4	1999	120	NA	0.71	0.09	NA	4	Morphology	1	1	2	PrimedLD	1	1	12	RT	0.09	0.00
Peng, Liu Yanping et al.	1a	1994	24	NA	0.71	0.66	NA	4	Morphology	1	1	2	PrimedLD	1	1	16	RT	0.64	0.03
Peng, Liu Yanping et al.	1b	1994	24	NA	0.71	0.06	NA	NA	Morph.Type	1	1	2	PrimedLD	1	1	16	RT	0.05	0.02
Peng, Liu Ying et al.	1a	1999	21	NA	0.71	0.34	2	NA	Char.Freq	1	1	1	LD	2	2	20	RT	0.33	0.03

Peng, Liu Ying et al.	1b	1999	21	NA	0.71	0.03	1	NA	Char.Freq	1	1	1	LD	2	2	20	RT	0.03	0.03
Peng, Liu Ying et al.	2a	1999	17	NA	0.71	0.83	NA	NA	Char.Freq	1	1	1	LD	2	2	20	RT	0.79	0.04
Peng, Liu Ying et al.	2b	1999	17	NA	0.71	-0.47	NA	NA	Char.Freq	1	1	1	LD	2	2	20	RT	-0.45	0.03
Peng, Liu Ying et al.	3a	1999	30	NA	0.71	0.39	NA	1	Morph.Ortho	1	1	2	PrimedLD	2	2	20	RT	0.38	0.02
Peng, Liu Ying et al.	3b	1999	30	NA	0.71	0.03	NA	1	Morph.Ortho	1	1	2	PrimedLD	2	2	20	RT	0.03	0.02
Shen et al.	1	2018	36	22.5	0.70	0.25	NA	3	Morph.Seman	1	2	4	Boundary	2	1	24	GD	0.25	0.02
Shen et al.	2a	2018	36	23.7	0.85	0.25	NA	3	Morph.Seman	1	2	4	Boundary	2	1	20	GD	0.24	0.01
Shen et al.	2b	2018	36	23.7	0.78	-0.13	NA	3	Morph.Seman	1	2	4	Boundary	2	1	20	GD	-0.12	0.01
Tan & Peng	1	1991	15	NA	0.71	0.93	NA	2	Morph.Phono	1	1	2	PrimedLD	1	1	30	RT	0.88	0.05
Tan & Peng	2	1991	15	NA	0.71	0.96	NA	2	Morph.Phono	1	1	2	PrimedLD	1	1	30	RT	0.91	0.05
Tan & Peng	3	1991	15	NA	0.71	1.03	NA	1	Morph.Ortho	1	1	2	PrimedLD	1	1	30	RT	0.97	0.05
Tan & Perfetti	2a	1999	18	NA	0.71	0.39	NA	2	Num.Pronu	1	1	1	LD	2	1	11	RT	0.37	0.03
Tan & Perfetti	2b	1999	18	NA	0.71	0.51	NA	2	Num.Pronu	1	1	1	LD	2	1	11	RT	0.48	0.03
Tian	1a	2009	30	22.0	0.71	0.71	NA	NA	Char.Freq	1	1	1	LD	1	1	24	RT	0.69	0.02
Tian	1c	2009	30	22.0	0.71	0.44	NA	NA	Char.Freq	1	1	1	LD	1	1	24	RT	0.43	0.02
Tian	2a	2009	30	22.0	0.71	0.68	NA	NA	Char.Freq	1	2	3	Reading	1	1	24	GD	0.66	0.02
Tian	2c	2009	30	22.0	0.71	0.09	NA	NA	Char.Freq	1	2	3	Reading	1	1	24	GD	0.09	0.02
Tsai, Kliegl et al.	1a	2012	50	22.8	0.71	0.12	NA	1	Morph.Ortho	2	2	4	Boundary	2	1	10	GD	0.12	0.01
Tsai, Kliegl et al.	1b	2012	50	22.8	0.71	-0.05	NA	2	Morph.Phono	2	2	4	Boundary	2	1	10	GD	-0.05	0.01
Tsai, Kliegl et al.	1c	2012	50	22.8	0.71	0.27	NA	3	Morph.Seman	2	2	4	Boundary	2	1	10	GD	0.26	0.01
Tsai, Lee et al.	1a	2006	20	NA	0.71	0.36	NA	NA	Neigh.Size	2	1	1	LD	2	1	30	RT	0.35	0.03
Tsai, Lee et al.	2a	2006	40	NA	0.71	0.73	NA	NA	Neigh.Size	2	2	3	Reading	2	1	30	GD	0.71	0.02
Tsang	1a	2021	32	NA	0.71	0.64	NA	3	Morph.Seman	2	1	2	PrimedLD	2	1	6	RT	0.62	0.02
Tsang	1b	2021	32	NA	0.71	-0.06	NA	1	Morph.Ortho	2	1	2	PrimedLD	2	1	6	RT	-0.06	0.02
Tsang	1c	2021	32	NA	0.71	-0.13	NA	2	Morph.Phono	2	1	2	PrimedLD	2	1	6	RT	-0.13	0.02
Tsang	1d	2021	32	NA	0.71	0.62	NA	4	Morphology	2	1	2	PrimedLD	2	1	6	RT	0.61	0.02
Tsang	2a	2021	40	NA	0.71	0.42	NA	3	Morph.Seman	2	1	2	PrimedLD	2	1	5	RT	0.41	0.02
Tsang	2b	2021	40	NA	0.71	0.03	NA	2	Morph.Phono	2	1	2	PrimedLD	2	1	5	RT	0.03	0.01
Tsang	2c	2021	40	NA	0.71	0.43	NA	4	Morphology	2	1	2	PrimedLD	2	1	5	RT	0.42	0.02
Tsang	2d	2021	40	NA	0.71	0.54	NA	4	Morphology	2	1	2	PrimedLD	2	1	5	RT	0.53	0.02
Tsang	3a	2021	54	NA	0.71	0.50	NA	3	Morph.Seman	2	1	2	PrimedLD	2	1	5	RT	0.49	0.01
Tsang	3b	2021	54	NA	0.71	0.45	NA	3	Morph.Seman	2	1	2	PrimedLD	2	1	5	RT	0.44	0.01

Tsang & Chen, H.	1a	2014	48	NA	0.71	0.62	NA	1	Morph.Ortho	2	1	2	PrimedLD	2	1	6	RT	0.61	0.01
Tsang & Chen, H.	1b	2014	48	NA	0.71	-0.14	NA	1	Morph.Ortho	2	1	2	PrimedLD	2	1	6	RT	-0.14	0.01
Tsang & Chen, H.	1c	2014	48	NA	0.71	0.35	NA	3	Trans	2	1	2	PrimedLD	2	1	12	RT	0.35	0.01
Tsang & Chen, H.	2	2014	30	NA	0.71	0.35	NA	3	Morph.Seman	2	1	2	PrimedLD	2	1	8	RT	0.34	0.02
Tsang & Chen, H.	3a	2014	28	NA	0.71	0.70	NA	1	Morph.Ortho	2	1	2	PrimedLD	2	1	6	RT	0.68	0.02
Tsang & Chen, H.	3b	2014	28	NA	0.71	0.04	NA	1	Morph.Ortho	2	1	2	PrimedLD	2	1	6	RT	0.04	0.02
Tsang & Chen, H.	3c	2014	28	NA	0.71	0.38	NA	3	Trans	2	1	2	PrimedLD	2	1	12	RT	0.37	0.02
Tsang & Chen, H.	1a	2013	38	NA	0.71	0.23	NA	3	Morph.Seman	2	1	2	PrimedLD	2	1	10	RT	0.22	0.02
Tsang & Chen, H.	1b	2013	38	NA	0.71	-0.14	NA	3	Morph.Seman	2	1	2	PrimedLD	2	1	10	RT	-0.14	0.01
Tsang & Chen, H.	2a	2013	40	NA	0.71	0.47	NA	3	Morph.Seman	2	1	2	PrimedLD	2	1	10	RT	0.46	0.02
Tsang & Chen, H.	2b	2013	40	NA	0.71	0.67	NA	3	Morph.Seman	2	1	2	PrimedLD	2	1	10	RT	0.65	0.02
Tsang et al.	1a	2014	24	NA	0.71	0.04	NA	3	Morph.Seman	2	1	2	PrimedLD	2	1	12	RT	0.04	0.02
Tsang et al.	1b	2014	24	NA	0.71	0.47	NA	4	Morphology	2	1	2	PrimedLD	2	1	12	RT	0.45	0.03
Tsang et al.	1c	2014	24	NA	0.71	0.42	NA	1	Morph.Ortho	2	1	2	PrimedLD	2	1	12	RT	0.41	0.02
Tsang et al.	2a	2014	24	NA	0.71	0.33	NA	3	Morph.Seman	2	1	2	PrimedLD	2	1	12	RT	0.32	0.02
Tsang et al.	2b	2014	24	NA	0.71	0.43	NA	4	Morphology	2	1	2	PrimedLD	2	1	12	RT	0.42	0.02
Tsang et al.	2c	2014	24	NA	0.71	0.08	NA	1	Morph.Ortho	2	1	2	PrimedLD	2	1	12	RT	0.08	0.02
Tsang et al.	3a	2014	24	NA	0.71	0.30	NA	3	Morph.Seman	2	1	2	PrimedLD	2	1	12	RT	0.29	0.02
Tsang et al.	3b	2014	24	NA	0.71	0.30	NA	4	Morphology	2	1	2	PrimedLD	2	1	12	RT	0.29	0.02
Tsang et al.	3c	2014	24	NA	0.71	0.04	NA	1	Morph.Ortho	2	1	2	PrimedLD	2	1	12	RT	0.03	0.02
Wang, C. & Peng	1a	2000	96	NA	0.71	0.35	NA	4	Morphology	1	1	2	PrimedLD	1	1	8	RT	0.35	0.01
Wang, C. & Peng	1b	2000	96	NA	0.71	0.27	NA	4	Morphology	1	1	2	PrimedLD	1	1	8	RT	0.27	0.01
Wang, C. & Peng	1c	2000	96	NA	0.71	0.31	NA	4	Morphology	1	1	2	PrimedLD	1	1	8	RT	0.31	0.01
Wang, C. & Peng	1d	2000	96	NA	0.71	0.06	NA	3	Morph.Seman	1	1	2	PrimedLD	1	1	8	RT	0.05	0.01
Wang, J. et al.	1	2023	40	23.3	0.38	-0.03	NA	3	Plau	1	2	3	Reading	2	1	12	GD	-0.03	0.03
Wang, Yongsheng. et al.	1	2022	36	20.7	0.71	0.11	NA	NA	Char.Freq	1	2	3	Reading	1	1	20	GD	0.11	0.02
Wang, Yongsheng. & He	1a	2022	36	20.5	0.71	0.01	2	NA	Char.Freq	1	2	3	Reading	1	1	10	GD	0.01	0.02
Wang, Yongsheng. & He	1b	2022	36	20.5	0.71	-0.04	1	NA	Char.Freq	1	2	3	Reading	1	1	10	GD	-0.04	0.02
Wang, Yuling, Jiang et al.	1a	2021	24	21.9	0.71	0.02	2	2	Morph.Phono	1	1	2	PrimedSD	2	1	60	RT	0.02	0.02
Wang, Yuling, Jiang et al.	1b	2021	24	21.9	0.71	0.47	1	2	Morph.Phono	1	1	2	PrimedSD	2	1	60	RT	0.45	0.03
Wang, Yuling, Li, Z. et al.	1a	2024	30	23.1	0.71	0.24	2	4	Morphology	1	1	2	PrimedLD	2	1	55	RT	0.23	0.02
Wang, Yuling, Li, Z. et al.	1b	2024	30	23.1	0.71	0.01	2	3	Morph.Seman	1	1	2	PrimedLD	2	1	55	RT	0.01	0.02

Wang, Yuling, Li, Z. et al.	1c	2024	30	23.1	0.71	0.12	2	1	Morph.Ortho	1	1	2	PrimedLD	2	1	55	RT	0.11	0.02
Wang, Yuling, Li, Z. et al.	1d	2024	30	23.1	0.71	0.12	2	4	Morphology	1	1	2	PrimedLD	2	1	55	RT	0.12	0.02
Wang, Yuling, Li, Z. et al.	2a	2024	28	23.1	0.71	0.22	2	4	Morphology	1	1	2	PrimedLD	2	1	55	RT	0.21	0.02
Wang, Yuling, Li, Z. et al.	2b	2024	28	23.1	0.71	0.11	2	3	Morph.Seman	1	1	2	PrimedLD	2	1	55	RT	0.10	0.02
Wang, Yuling, Li, Z. et al.	2c	2024	28	23.1	0.71	0.07	2	1	Morph.Ortho	1	1	2	PrimedLD	2	1	55	RT	0.07	0.02
Wang, Yuling, Li, Z. et al.	2d	2024	28	23.1	0.71	0.18	2	4	Morphology	1	1	2	PrimedLD	2	1	55	RT	0.18	0.02
Wei et al.	2a	2023	34	22.0	0.90	0.07	NA	3	Trans	1	1	1	LD	2	1	52	RT	0.07	0.01
Wei et al.	2b	2023	34	22.0	0.92	0.23	NA	NA	Morph.Type	1	1	1	LD	2	1	52	RT	0.22	0.00
Wei et al.	2c	2023	34	22.0	0.86	0.16	NA	NA	Morph.Type	1	1	1	LD	2	1	52	RT	0.15	0.01
Wong et al.	1a	2014	22	20.0	0.71	0.23	NA	1	Morph.Ortho	2	1	2	PrimedLD	2	1	72	RT	0.22	0.03
Wong et al.	1b	2014	22	20.0	0.71	-0.01	NA	2	Morph.Phono	2	1	2	PrimedLD	2	1	72	RT	-0.01	0.02
Wong et al.	1c	2014	22	20.0	0.71	0.30	NA	1	Morph.Ortho	2	1	2	PrimedLD	2	1	72	RT	0.29	0.03
Wong et al.	1d	2014	22	20.0	0.71	0.08	NA	2	Morph.Phono	2	1	2	PrimedLD	2	1	72	RT	0.07	0.02
Wu, J. et al.	1a	2020	25	22.5	0.71	0.25	NA	3	Morph.Seman	1	1	2	PrimedLD	1	1	48	RT	0.24	0.02
Wu, J. et al.	1b	2020	25	22.5	0.71	0.70	NA	1	Morph.Ortho	1	1	2	PrimedLD	1	1	46	RT	0.68	0.03
Wu, J. et al.	1c	2020	25	22.5	0.71	-0.15	NA	2	Morph.Phono	1	1	2	PrimedLD	1	1	46	RT	-0.15	0.02
Wu, J. et al.	1d	2020	25	22.5	0.71	0.89	NA	4	Morphology	1	1	2	PrimedLD	1	1	46	RT	0.86	0.03
Wu, Q. et al.	1	2013	32	NA	0.71	0.36	NA	1	Morph.Ortho	1	1	2	PrimedLD	1	2	29	RT	0.35	0.02
Wu, Q. et al.	2	2013	32	NA	0.71	0.00	NA	1	Morph.Ortho	1	1	2	PrimedLD	1	2	29	RT	0.00	0.02
Wu, Y., Duan et al.	1a	2020	26	21.1	0.71	0.13	NA	3	Morph.Seman	1	1	2	PrimedLD	2	1	40	RT	0.12	0.02
Wu, Y., Duan et al.	1b	2020	26	21.1	0.71	0.14	NA	3	Morph.Seman	1	1	2	PrimedLD	2	1	40	RT	0.14	0.02
Wu, Y., Duan et al.	1c	2020	26	21.1	0.71	0.38	NA	4	Morphology	1	1	2	PrimedLD	2	1	40	RT	0.37	0.02
Wu, Y., Duan et al.	1d	2020	26	21.1	0.71	0.23	NA	1	Morph.Ortho	1	1	2	PrimedLD	2	1	40	RT	0.22	0.02
Wu, Y., Duan et al.	1e	2020	26	21.1	0.71	0.36	NA	4	Morphology	1	1	2	PrimedLD	2	1	40	RT	0.35	0.02
Wu, Y., Duan et al.	1f	2020	26	21.1	0.71	0.23	NA	1	Morph.Ortho	1	1	2	PrimedLD	2	1	40	RT	0.23	0.02
Wu, Y. & Li, T.	1a	2018	27	24.4	0.71	0.36	NA	1	Morph.Ortho	1	1	2	PrimedLD	1	1	20	RT	0.35	0.02
Wu, Y. & Li, T.	1b	2018	27	24.4	0.71	-0.04	NA	1	Morph.Ortho	1	1	2	PrimedLD	1	1	20	RT	-0.04	0.02
Wu, Y., Tsang et al.	1a	2017	24	20.0	0.71	0.18	NA	3	Morph.Seman	2	1	2	PrimedLD	2	1	36	RT	0.17	0.02
Wu, Y., Tsang et al.	1b	2017	24	20.0	0.71	0.31	NA	3	Morph.Seman	2	1	2	PrimedLD	2	1	36	RT	0.30	0.02
Wu, Y., Tsang et al.	1c	2017	24	20.0	0.71	0.33	NA	4	Morphology	2	1	2	PrimedLD	2	1	36	RT	0.32	0.02
Wu, Y., Tsang et al.	1d	2017	24	20.0	0.71	0.15	NA	1	Morph.Ortho	2	1	2	PrimedLD	2	1	36	RT	0.14	0.02
Wu, Y., Tsang et al.	1e	2017	24	20.0	0.71	0.49	NA	4	Morphology	2	1	2	PrimedLD	2	1	36	RT	0.48	0.03

Wu, Y., Tsang et al.	1f	2017	24	20.0	0.71	0.19	NA	1	Morph.Ortho	2	1	2	PrimedLD	2	1	36	RT	0.18	0.02
Wu, Y., Tsang et al.	1g	2017	24	20.0	0.71	0.22	NA	4	Morphology	2	1	2	PrimedLD	2	1	36	RT	0.21	0.02
Wu, Y., Tsang et al.	1h	2017	24	20.0	0.71	0.35	NA	4	Morphology	2	1	2	PrimedLD	2	1	36	RT	0.34	0.02
Xiong et al.	1a	2023	82	NA	0.92	0.03	2	NA	Char.Freq	1	1	1	LD	2	1	15	RT	0.03	0.00
Xiong et al.	1b	2023	82	NA	0.70	-0.18	1	NA	Char.Freq	1	1	1	LD	2	1	15	RT	-0.18	0.01
Xiong et al.	2a	2023	82	NA	0.83	0.14	2	NA	Char.Freq	1	1	1	Naming	2	1	15	RT	0.14	0.00
Xiong et al.	2b	2023	82	NA	0.92	0.10	1	NA	Char.Freq	1	1	1	Naming	2	1	15	RT	0.09	0.00
Xiong et al.	3a	2023	82	NA	0.52	0.04	2	NA	Char.Freq	1	2	3	Reading	2	1	15	GD	0.04	0.01
Xiong et al.	3b	2023	82	NA	0.56	-0.20	1	NA	Char.Freq	1	2	3	Reading	2	1	15	GD	-0.20	0.01
Xiong et al.	1a	2021	119	NA	0.71	0.04	2	NA	Neigh.Size	1	1	1	LD	2	1	20	RT	0.04	0.00
Xiong et al.	1b	2021	119	NA	0.71	0.11	1	NA	Neigh.Size	1	1	1	LD	2	1	20	RT	0.10	0.00
Yan, G. et al.	1a	2006	29	NA	0.71	0.68	NA	NA	Char.Freq	1	2	3	Reading	2	1	24	GD	0.67	0.02
Yan, G. et al.	1b	2006	29	NA	0.71	0.26	NA	NA	Char.Freq	1	2	3	Reading	2	1	24	GD	0.26	0.02
Yan, G. et al.	1	2013	31	NA	0.71	0.07	NA	2	Homoph. Dense	1	2	3	Reading	1	1	18	GD	0.07	0.02
Yan, M., Richter et al.	1a	2009	51	NA	0.71	0.22	NA	1	Morph.Ortho	1	2	4	Boundary	2	1	10	GD	0.22	0.01
Yan, M., Richter et al.	1b	2009	51	NA	0.71	0.20	NA	2	Morph.Phono	1	2	4	Boundary	2	1	10	GD	0.20	0.01
Yan, M., Richter et al.	1c	2009	51	NA	0.71	0.27	NA	3	Morph.Seman	1	2	4	Boundary	2	1	10	GD	0.26	0.01
Yan, M., Zhou, W. et al.	1a	2012	50	NA	0.71	0.51	NA	3	Morph.Seman	1	2	4	Boundary	2	1	18	GD	0.50	0.01
Yan, M., Zhou, W. et al.	1b	2012	50	NA	0.71	0.28	NA	3	Morph.Seman	1	2	4	Boundary	2	1	18	GD	0.28	0.01
Yang, H. et al.	1	2022	32	NA	0.71	0.75	NA	1	Morph.Ortho	1	1	2	PrimedLD	2	1	28	RT	0.73	0.02
Yang, H. et al.	2a	2022	66	NA	0.80	0.67	NA	1	Morph.Ortho	1	1	2	PrimedLD	2	1	20	RT	0.66	0.01
Yang, H. et al.	2b	2022	66	NA	0.80	0.27	NA	1	Morph.Ortho	1	1	2	PrimedLD	2	1	20	RT	0.26	0.01
Yang Hsien-Ming. & McConkie	1a	1999	13	NA	0.71	0.46	NA	1	Stroke	2	2	3	Reading	2	2	20	GD	0.43	0.04
Yang Hsien-Ming. & McConkie	1b	1999	13	NA	0.71	0.62	NA	1	Stroke	2	2	3	Reading	2	2	20	GD	0.58	0.05
Yang Hsien-Ming. & McConkie	1c	1999	13	NA	0.71	0.07	NA	1	Stroke	2	2	3	Reading	2	2	20	GD	0.07	0.04
Yang Hsien-Ming. & McConkie	1d	1999	13	NA	0.71	0.24	NA	1	Stroke	2	2	3	Reading	2	2	20	GD	0.23	0.04
Yang, J. et al.	1	2012	40	NA	0.71	-0.06	NA	3	Plau	1	2	3	Reading	2	1	10	GD	-0.06	0.01
Yao, Slattery et al.	1a	2022	42	NA	0.52	0.10	NA	NA	Neigh.Size	1	2	3	Reading	2	1	40	GD	0.10	0.02
Yao, Slattery et al.	1b	2022	42	NA	0.56	0.43	NA	NA	Neigh.Size	1	2	3	Reading	2	1	40	GD	0.42	0.02
Yen et al.	2a	2008	30	NA	0.71	0.25	NA	3	Morph.Seman	2	2	4	Boundary	2	1	26	GD	0.24	0.02
Yen et al.	2b	2008	30	NA	0.71	0.50	NA	1	Morph.Ortho	2	2	4	Boundary	2	1	26	GD	0.49	0.02
Yen et al.	1	2012	27	NA	0.71	0.15	NA	1	Pos.Prob	2	2	3	Reading	2	1	24	GD	0.14	0.02
Yu, Lili et al.	1a	2021	60	20.4	0.75	-0.27	2	NA	Char.Freq	1	2	3	Reading	2	1	25	GD	-0.27	0.01

Yu, Lili et al.	1b	2021	60	20.4	0.77	-0.17	1	NA	Char.Freq	1	2	3	Reading	2	1	25	GD	-0.17	0.01
Yu, Linxin	1a	2006	66	NA	0.71	-0.05	2	3	Morph.Seman	1	1	2	PrimedLD	1	2	12	RT	-0.05	0.01
Yu, Linxin	1b	2006	66	NA	0.71	0.37	1	3	Morph.Seman	1	1	2	PrimedLD	1	2	12	RT	0.37	0.01
Zhang, B. & Peng	1a	1992	40	NA	0.71	0.32	NA	NA	Char.Freq	2	1	1	LD	2	2	10	RT	0.31	0.01
Zhang, B. & Peng	1b	1992	40	NA	0.71	0.52	NA	NA	Char.Freq	2	1	1	LD	2	2	10	RT	0.51	0.02
Zhang, B. & Peng	2a	1992	40	NA	0.71	0.23	NA	NA	Char.Freq	2	1	1	LD	2	2	10	RT	0.22	0.01
Zhang, B. & Peng	2b	1992	40	NA	0.71	0.90	NA	NA	Char.Freq	2	1	1	LD	2	2	10	RT	0.88	0.02
Zhang, L.	1a	2011	37	NA	0.71	0.05	NA	3	Morph.Seman	1	1	2	PrimedLD	2	2	36	RT	0.05	0.02
Zhang, L.	1b	2011	37	NA	0.71	0.11	NA	3	Morph.Seman	1	1	2	PrimedLD	2	2	36	RT	0.11	0.02
Zhang, L.	2a	2011	37	NA	0.71	0.00	NA	3	Morph.Seman	1	1	2	PrimedLD	2	2	36	RT	0.00	0.02
Zhang, L.	2b	2011	37	NA	0.71	-0.02	NA	3	Morph.Seman	1	1	2	PrimedLD	2	2	36	RT	-0.02	0.02
Zhang, L.	3a	2011	37	NA	0.71	0.08	NA	3	Morph.Seman	1	1	2	PrimedLD	2	2	36	RT	0.08	0.02
Zhang, L.	3b	2011	37	NA	0.71	0.07	NA	3	Morph.Seman	1	1	2	PrimedLD	2	2	36	RT	0.07	0.02
Zhang, M.	3a	2012	48	21.5	0.71	0.15	2	1	Stroke	1	2	3	Reading	1	2	10	GD	0.14	0.01
Zhang, M.	3b	2012	48	21.5	0.71	0.05	1	1	Stroke	1	2	3	Reading	1	2	10	GD	0.05	0.01
Zhao, B. et al.	1a	2018	52	20.2	0.71	-0.03	2	NA	Char.Freq	1	2	3	Reading	1	1	15	GD	-0.03	0.01
Zhao, B. et al.	1b	2018	52	20.2	0.71	0.13	1	NA	Char.Freq	1	2	3	Reading	1	1	15	GD	0.12	0.01
Zhao, B. et al.	2a	2018	52	20.2	0.71	0.02	2	NA	Char.Freq	1	2	3	Reading	1	1	15	GD	0.02	0.01
Zhao, B. et al.	2b	2018	52	20.2	0.71	0.11	1	NA	Char.Freq	1	2	3	Reading	1	1	15	GD	0.11	0.01
Zhao, S. et al.	1a	2021	31	NA	0.71	0.23	NA	3	Morph.Seman	1	1	2	PrimedLD	2	1	30	RT	0.22	0.02
Zhao, S. et al.	1b	2021	31	NA	0.71	-0.16	NA	4	Morphology	1	1	2	PrimedLD	2	1	30	RT	-0.15	0.02
Zhao, S. et al.	1c	2021	31	NA	0.71	0.08	NA	1	Morph.Ortho	1	1	2	PrimedLD	2	1	30	RT	0.07	0.02
Zhao, S. et al.	1d	2021	31	NA	0.71	0.31	NA	4	Morphology	1	1	2	PrimedLD	2	1	30	RT	0.30	0.02
Zhao, S. et al.	1a	2017	18	22.8	0.71	0.30	NA	3	Morph.Seman	1	1	2	PrimedLD	1	1	40	RT	0.29	0.03
Zhao, S. et al.	1b	2017	18	22.8	0.71	0.32	NA	3	Morph.Seman	1	1	2	PrimedLD	1	1	40	RT	0.30	0.03
Zhao, S.	2a	2022	31	21.3	0.71	0.28	NA	3	Morph.Seman	1	1	2	PrimedLD	1	2	20	RT	0.28	0.02
Zhao, S.	2b	2022	31	21.3	0.71	0.30	NA	3	Morph.Seman	1	1	2	PrimedLD	1	2	20	RT	0.29	0.02
Zhao, S.	2c	2022	31	21.3	0.71	0.08	NA	4	Morphology	1	1	2	PrimedLD	1	2	20	RT	0.08	0.02
Zhao, S.	2d	2022	31	21.3	0.71	0.23	NA	4	Morphology	1	1	2	PrimedLD	1	2	20	RT	0.22	0.02
Zhao, S.	3a	2022	30	20.7	0.71	0.24	NA	3	Morph.Seman	1	1	2	PrimedLD	1	2	40	RT	0.24	0.02
Zhao, S.	3b	2022	30	20.7	0.71	0.23	NA	4	Morphology	1	1	2	PrimedLD	1	2	40	RT	0.23	0.02
Zhou, W. et al.	1a	2018	36	22.8	0.71	0.73	NA	1	Morph.Ortho	1	2	4	Boundary	2	1	22	GD	0.71	0.02

Zhou, W. et al.	1b	2018	36	22.8	0.71	0.09	NA	2	Morph.Phono	1	2	4	Boundary	2	1	22	GD	0.09	0.02
Zhou, X. et al.	1a	1999	137	NA	0.71	0.59	NA	4	Morphology	1	1	2	PrimedLD	2	1	10	RT	0.58	0.00
Zhou, X. et al.	1b	1999	52	NA	0.71	0.34	NA	1	Morph.Ortho	1	1	2	PrimedLD	2	1	10	RT	0.34	0.01
Zhou, X. et al.	1e	1999	45	NA	0.71	0.34	NA	1	Morph.Ortho	1	1	2	PrimedLD	2	1	10	RT	0.33	0.01
Zhou, X. et al.	1f	1999	40	NA	0.71	-0.02	NA	1	Morph.Ortho	1	1	2	PrimedLD	2	1	10	RT	-0.02	0.01
Zhou, X. et al.	1c	1999	137	NA	0.71	-0.01	NA	2	Morph.Phono	1	1	2	PrimedLD	2	1	10	RT	-0.01	0.00
Zhou, X. et al.	1d	1999	137	NA	0.71	0.26	NA	3	Morph.Seman	1	1	2	PrimedLD	2	1	10	RT	0.26	0.00
Zhou, X. et al.	2a	1999	146	NA	0.71	0.79	NA	4	Morphology	1	1	2	PrimedLD	2	1	10	RT	0.79	0.01
Zhou, X. et al.	2b	1999	146	NA	0.71	0.33	NA	1	Morph.Ortho	1	1	2	PrimedLD	2	1	10	RT	0.33	0.00
Zhou, X. et al.	2c	1999	146	NA	0.71	0.11	NA	2	Morph.Phono	1	1	2	PrimedLD	2	1	10	RT	0.11	0.00
Zhou, X. et al.	2d	1999	146	NA	0.71	0.25	NA	3	Morph.Seman	1	1	2	PrimedLD	2	1	10	RT	0.25	0.00
Zhou, X. et al.	3a	1999	136	NA	0.71	0.63	NA	4	Morphology	1	1	2	PrimedLD	2	1	10	RT	0.62	0.01
Zhou, X. et al.	3b	1999	136	NA	0.71	0.26	NA	1	Morph.Ortho	1	1	2	PrimedLD	2	1	10	RT	0.25	0.00
Zhou, X. et al.	3c	1999	136	NA	0.71	-0.01	NA	2	Morph.Phono	1	1	2	PrimedLD	2	1	10	RT	-0.01	0.00
Zhou, X. et al.	3d	1999	136	NA	0.71	0.26	NA	3	Morph.Seman	1	1	2	PrimedLD	2	1	10	RT	0.26	0.00
Zhou, X. et al.	4a	1999	29	NA	0.71	0.85	NA	4	Morphology	1	1	2	PrimedLD	2	1	22	RT	0.83	0.03
Zhou, X. et al.	4b	1999	32	NA	0.71	0.16	NA	4	Morphology	1	1	2	PrimedLD	2	1	22	RT	0.16	0.02

Note: A more detailed data file is available on the Open Science Framework. The meaning of each variable and how they were coded is available in Table S1 in Supplementary Materials 1. The number represents multiple levels for each variable, and the specific definition was also presented in Table S1.

Appendix B

Additional Moderator Analyses

Whole-Word Frequency

Although whole-word frequency has been reported to interact with properties of their constituents, we did not find evidence for such moderation (p = .613). The heterogeneity remained significant after accounting for whole-word frequency, $Q_E(53) = 170.30$, $p < .001$. Specifically, the constituent effect sizes were not significantly different from zero in experiments where the word frequency was either low ($g_{rm} = 0.04$, 95% CI [−0.03, 0.12], p = .234) or high ($g_{rm} = 0.07$, 95% CI [−0.01, 0.15], p = .068). Moreover, in eight studies from five different articles, word frequency and character frequency were manipulated simultaneously. We still did not find evidence for the moderation of whole-word frequency in the analysis targeting at character frequency effect (p = .613). The effect was not significant when the compound words were neither low ($g_{rm} = -0.03$, 95% CI [−0.14, 0.08], p = .615) nor high frequency ($g_{rm} = 0.03$, 95% CI [−0.08, 0.14], p = .603). In contrast, the effect of whole-word frequency was significant, and the estimation for the whole-word frequency effects extracted from these studies showed a small-to-medium effect ($g_{rm} = 0.30$, 95% CI [0.19, 0.41], $p < .001$)[16].

Stimulus Onset Asynchrony (SOA)

Several priming experiments have also varied the SOA to determine if constituent effects occur during the early or later stages of compound-word processing. We therefore

[16] 16 effect sizes were extracted from the five articles (Peng et al., 1999; Wang & He, 2022; Xiong et al., 2022; Yu et al., 2021; Zhao et al., 2018); in their studies, the independent variables were character frequency and whole-word frequency, and they all used a within-subject design. We fit a three-level random-effects model to estimate the overall whole-word frequency effect and set the correlation coefficient to be 0.71, which was the same as the main analysis for constituent effect. The list of studies was in Supplementary Materials 2.

analyzed the potential moderating effect of SOA to better understand the time course of constituent processing and its relation to orthographic, phonological, and semantic processing. The SOA (range: 40 to 600 ms) was first examined as a continuous variable based on 114 effect sizes from 48 priming experiments; this analysis showed no significant effect of SOA ($p = .924$). It was still not significant for morpho-orthographic priming ($b = -0.05$, $t = -1.07$, $p = .296$), morpho-phonological priming ($b = 0.09$, $t = 0.72$, $p = .484$), or morpho-semantic priming ($b = -0.03$, $t = -1.05$, $p = .302$).

Supplementary Materials 1

Table S1

Code Book

effectsize.id	Unique effect size number
articleName	Title of article
authors	Author(s) of article
exp	Serial number of the experiment in the article. When multiple effect sizes were extracted from an experiment, they were distinguished by letters.
sample.id	Unique sample number. Note: studies sharing participants but using different tasks or different manipulations were treated as different; studies reported multiple dependent effect sizes are considered part of the same sample. This cluster structure is used in later meta-regressions with RVE and in aggregation methods.
subject.id	Unique subject number
article.id	Unique article number
PubYear	Year of publication
sample.n	Sample size (when a study reports the exclusion of subjects, only record the number of subjects in the data analysis)
sample.desc	Descriptive information of the sample
age	Average age of participants; NA if not reported
r	Correlation between the two conditions (estimated at 0.7091 if the value was unavailable from the article or raw data)
Cohens	Effect sizes calculated directly from the M's and SD's, t-values, F-values, or p-values
Position	Which constituent was manipulated (1=first; 2=second; NA=no explicit manipulation of one constituent)
WordFrequency	Compound word frequency (1 = low; 2 = high; NA = unreported)
WFsource	Sources of word frequency measures
ProcessingLevel	Level of processing to which the variable mainly relates (1 = orthographic processing level; 2 = phonological processing level; 3 = semantic processing level; NA = controversial)
Manipulation	Variable of constituent manipulated in the study (Char.Freq=character frequency; Cont.Divers = contextual diversity; Homoph.Dense = homophone density; Morph.Ortho = morpho-orthographic priming; Morph.Phono = morpho-phonological priming; Morph.Relation = morphemic relation priming; Morph.Seman = morpho-semantic priming; Morph.Type = morpheme type; Morphology = morphology priming; Neigh.Size = neighborhood size; Num.Mean = number of meanings; Num.Pron = number of pronunciation; Plau = plausibility of first constituent; Stroke = number of strokes; Trans = semantic transparency)
WritingSystem	Writing system of stimulus (1 = simplified Chinese; 2 = traditional Chinese)
PresentationMethod	Whether the words were embedded in sentences (1 = in isolation; 2 = in sentence)
IsolateParadigm	Paradigms of the target words in isolated presentation (1 = isolated-word; 2 = prime)
SentenceParadigm	Paradigms of the target words in sentence presentation (1 = natural sentence reading; 2 = reading using a preview paradigm)
Task	Experimental task (LD = lexical decision; Naming; SD = semantic decision; PrimedLD = primed lexical decision; PrimedN = Primed

	naming; PrimedSD = primed semantic decision; Reading = natural reading; Boundary = reading with a boundary paradigm)
PubLang	Publication language (1 = Chinese; 2 = English)
PubType	Publication type (1 = journal articles, 2 = other sources)
PrimeD	Prime duration, indicating how long the prime stimulus were presented to the participants (in milliseconds). Coded as a continuous variable.
SOA	Stimulus onset asynchrony in priming studies, indicating the interval between the onset of the prime and the onset of the target. Coded as a continuous variable.
SetSize	The number of items per condition in the experiment. Coded as a continuous variable.
DV	Measurement (RT = response time; GD = gaze duration)
yi	Hedge's g
vi	Sampling variance

Supplementary Materials 2

Table S2

Description of Studies in Meta-Analysis of Whole-word Frequency Effects

Authors	Expt	Publication Year	Sample N	r	Cohens *d*	Task	DV	yi	vi
Peng, Liu Ying et al.	1a	1999	21	0.71	0.50	LD	RT	0.48	0.03
Peng, Liu Ying et al.	1b	1999	21	0.71	0.73	LD	RT	0.71	0.03
Wang & He	1a	2022	36	0.71	0.25	Reading	Gaze duration	0.25	0.02
Wang & He	1b	2022	36	0.71	0.21	Reading	Gaze duration	0.21	0.02
Xiong et al.	1a	2022	82	0.71	0.55	LD	RT	0.55	0.01
Xiong et al.	1b	2022	82	0.71	0.40	LD	RT	0.39	0.01
Xiong et al.	2a	2022	82	0.71	0.18	Naming	RT	0.18	0.01
Xiong et al.	2b	2022	82	0.71	0.15	Naming	RT	0.15	0.01
Xiong et al.	3a	2022	82	0.71	0.34	Reading	Gaze duration	0.34	0.01
Xiong et al.	3b	2022	82	0.71	0.11	Reading	Gaze duration	0.11	0.01
Yu et al.	1a	2021	60	0.71	0.33	Reading	Gaze duration	0.33	0.01
Yu et al.	1b	2021	60	0.71	0.54	Reading	Gaze duration	0.53	0.01
Zhao et al.	1a	2018	52	0.71	0.15	Reading	Gaze duration	0.15	0.01
Zhao et al.	1b	2018	52	0.71	0.30	Reading	Gaze duration	0.29	0.01
Zhao et al.	2a	2018	52	0.71	0.10	Reading	Gaze duration	0.10	0.01
Zhao et al.	2b	2018	52	0.71	0.25	Reading	Gaze duration	0.25	0.01

Supplementary Materials 3

Meta-analysis for ERP studies

Methods

Selection of Studies. The search strategy (from identification to screening) was the same as that for the behavioral studies reported in the main text. We excluded 948 articles after screening their titles and abstracts, and added 15 articles from other sources, leaving 25 texts to be assessed for eligibility. The lead author then downloaded and read the remaining 25 texts. Based on our exclusion criteria, for components at ~200 ms, 12 articles were included in the meta-analysis of ERP studies, allowing 32 effect sizes to be extracted; for components at ~400 ms, 15 articles were included in the meta-analysis of ERP studies, allowing 41 effect sizes to be extracted. (See Figure S1 for a flowchart of literature research, and Tables S3 and S4 for the lists of all included studies in the two meta-analyses.)

Inclusion and Exclusion Criteria. Full-text articles were assessed for eligibility based on the criteria similar to that applied to the meta-analysis for behavioral measures, except that the measures requiring components having peak amplitudes at ~200 ms or 400 ms.

Data Coding Procedures. For each eligible study, the lead author extracted all information required to calculate effect sizes (i.e., sample sizes, means and standard deviation, *t*- or *F*-values), the variables to be assessed as potential moderators (i.e., manipulation, writing system, publication type; see Table S7), and other descriptive information. The Cohen's *d* was first calculated and then corrected to get Hedges's g_{rm}. The direction of effect size was deemed positive if the amplitude of the experimental condition was smaller than that of control condition, which is consistent with the interpretation of constituent effects estimated for behavioral measures.

Results for Component at ~200 ms

We extracted 32 effect sizes from 12 articles reporting 12 studies (total *N* = 288 participants). The publication years of the articles identified ranged from 2012 to 2024 (*M* = 2018, Median = 2017). All studies used within-subject designs and university students as participants with sample sizes ranging from 16 to 32. All samples were native Chinese speakers. All but two[17] of the articles were written in English; all but one[18] of the articles were peer-reviewed and published in journals. Among all effect sizes, 27 were from studies with simplified Chinese, and 5 with traditional Chinese. The presentation methods, experimental tasks and manipulations, and detailed descriptive statistics of the numbers of effect sizes, studies, and moderators for each specific task are summarized in Table S5. There were 26 effects assessed in priming studies (25 in lexical decision and one in semantic decision), including manipulations of morphology, morpho-orthography, morpho-phonology, and morpho-semantics, as well as morphemic-relatedness priming. Three effects from the same study were assessed using *rapid serial visual presentation (RSVP)*, with one study manipulating the consistency of morpho-orthography, morpho-semantics, or morphology between the prime and target words. The other three effects were from the same study involving lexical decision of isolated words in which character frequency was manipulated.

Results for Component at ~400 ms

We extracted a total of 41 effect sizes from 15 articles reporting 15 studies (total *N* = 371 participants). Among them, the 12 studies reporting a component at ~200 ms also reported effects observed on components at ~400 ms, providing 32 effect sizes. There were another three studies in three articles only reporting the effects of components around 400

[17] Two articles were written in Chinese (J. Wu et al., 2020; S. Zhao et al., 2017).
[18] One article (Jia & C. Zhou, 2023) was preprinted in Research Square.

ms[19]. The publication years of the articles identified ranged from 2011 to 2024 (*M* = 2018, Median = 2017). All studies used within-subject designs and university students as participants with sample sizes ranging from 16 to 37. The descriptive statistics of 33 of these effect sizes is as described, involving components at ~200 ms. An additional 9 effects were assessed in three different studies using lexical decisions of isolated words, manipulating the number of meanings, morpheme type, and semantic transparency. The presentation methods, experimental tasks and manipulations, and detailed descriptive statistics of the numbers of effect sizes, studies, and moderators for each specific task are summarized in Table S6.

[19] Four effects from H. Huang and Lee (2018) and two from H. Huang et al. (2011) manipulated the number of meanings. Two effects of morpheme type and one of semantic transparency were extracted from Wei et al. (2023). These three studies did not report the results of components around 200 ms.

Table S3

Description of ERP Studies in Meta-Analysis of Constituent Effects for Component at ~200 ms

Authors	Expt	Publica-tion Year	Sample N	Age	r	Cohens *d*	Manipu-lation	Processing Level	Writing System	Task	Publication Language	Publication Type	Set Size	DV	Time Window	yi	vi
Chen, L., Fang et al.	1a	2017	32	18-35	0.71	0.02	Morphology	4	1	Reading	2	1	30	N200	100-250	0.02	0.02
Chen, L., Fang et al.	1b	2017	32	18-35	0.71	0.02	Morph.Seman	3	1	Reading	2	1	30	N200	100-250	0.02	0.02
Chen, L., Fang et al.	1c	2017	32	18-35	0.71	0.02	Morph.Ortho	1	1	Reading	2	1	30	N200	100-250	0.02	0.02
Jia, Wang, S. et al.	1	2013	18	21.3	0.71	0.16	Morph.Relation		1	PrimedLD	2	1	66	N200	180-260	0.15	0.03
Jia & Zhou, C.	1	2023	27	22.7	0.71	0.06	Morph.Relation		1	PrimedLD	2	2	36	N200	150-250	0.06	0.02
Wang, W. et al.	1a	2017	16	21.1	0.71	-0.47	Char.Freq		1	LD	2	1	40	P200	150-250	-0.45	0.04
Wang, W. et al.	1b	2017	16	21.1	0.71	0.39	Char.Freq		1	LD	2	1	40	P200	150-250	0.37	0.04
Wang, W. et al.	1c	2017	16	21.1	0.71	0.13	Char.Freq		1	LD	2	1	40	P200	150-250	0.13	0.03
Wang, Yuling, Jiang et al.	1	2021	24	21.9	0.71	0.02	Morph.Phono	2	1	PrimedSD	2	1	120	P200	160-280	0.02	0.02
Wang, Yuling, Li, Z. et al.	1a	2024	30	23.13	0.71	0.14	Morphology	4	1	PrimedLD	2	1	55	N250	200-250	0.14	0.02
Wang, Yuling, Li, Z. et al.	1b	2024	30	23.13	0.71	0.18	Morph.Seman	3	1	PrimedLD	2	1	55	N250	200-250	0.17	0.02
Wang, Yuling, Li, Z. et al.	1c	2024	30	23.13	0.71	0.01	Morph.Ortho	1	1	PrimedLD	2	1	55	N250	200-250	0.01	0.02
Wang, Yuling, Li, Z. et al.	1d	2024	30	23.13	0.71	0.20	Morphology	4	1	PrimedLD	2	1	55	N250	200-250	0.20	0.02
Wong et al.	1e	2014	22	20	0.71	0.45	Morph.Ortho	1	2	PrimedLD	2	1	72	N250	150-250	0.44	0.03
Wong et al.	1f	2014	22	20	0.71	0.02	Morph.Phono	2	2	PrimedLD	2	1	72	N250	150-250	0.02	0.02
Wu, J. et al.	2a	2020	25	24.1	0.71	0.40	Morph.Seman	3	1	PrimedLD	1	1	46	P200	120-220	0.39	0.02
Wu, J. et al.	2b	2020	25	24.1	0.71	0.34	Morph.Ortho	1	1	PrimedLD	1	1	46	P200	120-220	0.33	0.02
Wu, J. et al.	2c	2020	25	24.1	0.71	-0.29	Morph.Phono	2	1	PrimedLD	1	1	46	P200	120-220	-0.29	0.02
Wu, J. et al.	2d	2020	25	24.1	0.71	0.32	Morphology	4	1	PrimedLD	1	1	46	P200	120-220	0.31	0.02
Wu, Y., Duan et al.	1a	2020	26	21.12	0.71	0.02	Morph.Seman	3	1	PrimedLD	2	1	40	N250	200-300	0.02	0.02
Wu, Y., Duan et al.	1b	2020	26	21.12	0.71	0.02	Morph.Seman	3	1	PrimedLD	2	1	40	N250	200-300	0.02	0.02
Wu, Y., Duan et al.	1c	2020	26	21.12	0.71	0.42	Morphology	4	1	PrimedLD	2	1	40	N250	200-300	0.40	0.02
Wu, Y., Duan et al.	1d	2020	26	21.12	0.71	0.42	Morph.Ortho	1	1	PrimedLD	2	1	40	N250	200-300	0.40	0.02
Wu, Y., Duan et al.	1e	2020	26	21.12	0.71	0.26	Morphology	4	1	PrimedLD	2	1	40	N250	200-300	0.25	0.02
Wu, Y., Duan et al.	1f	2020	26	21.12	0.71	0.29	Morph.Ortho	1	1	PrimedLD	2	1	40	N250	200-300	0.28	0.02
Wu, Y., Tsang et al.	1a	2017	24	20	0.71	0.02	Morph.Seman	3	2	PrimedLD	2	1	72	N250	150-250	0.02	0.02
Wu, Y., Tsang et al.	1b	2017	24	20	0.71	0.46	Morphology	4	2	PrimedLD	2	1	72	N250	150-250	0.44	0.03
Wu, Y., Tsang et al.	1c	2017	24	20	0.71	0.48	Morph.Ortho	1	2	PrimedLD	2	1	72	N250	150-250	0.47	0.03

Zhang, J. et al	1a	2012	26	20.2	0.71	0.42	Morphology	4	1	PrimedLD	2	1	50	N200	196-236	0.41	0.02
Zhang, J. et al	1b	2012	26	20.2	0.71	0.16	Morphology	4	1	PrimedLD	2	1	50	N200	196-236	0.16	0.02
Zhao, S. et al.	1a	2017	18	22.8	0.71	0.52	Morph.Seman	3	1	PrimedLD	1	1	40	N250	200-250	0.50	0.03
Zhao, S. et al.	1b	2017	18	22.8	0.71	0.71	Morph.Seman	3	1	PrimedLD	1	1	40	N250	200-250	0.68	0.04

Note: A more detailed data file is available on the Open Science Framework. The meaning of each variable and how they were coded is available in Table S7 in Supplementary Materials 3.

Table S4

Description of ERP Studies in Meta-Analysis of Constituent Effects for Component at ~400 ms

Authors	Expt	Publica-tion Year	Sample N	Age	r	Cohens *d*	Manipu-lation	Processing Level	Writing System	Task	Publication Language	Publication Type	Set Size	DV	Time Window	yi	vi
Chen, L., Fang et al.	1a	2017	32	18-35	0.71	0.13	Morphology	4	1	Reading	2	1	30	N400	250-450	0.13	0.02
Chen, L., Fang et al.	1b	2017	32	18-35	0.71	0.19	Morph.Seman	3	1	Reading	2	1	30	N400	250-450	0.19	0.02
Chen, L., Fang et al.	1c	2017	32	18-35	0.71	0.22	Morph.Ortho	1	1	Reading	2	1	30	N400	250-450	0.21	0.02
Jia, Wang, S. et al.	1	2013	18	21.3	0.71	0.38	Morph.Relation		1	PrimedLD	2	1	66	N400	300-400	0.36	0.03
Jia & Zhou, C.	1	2023	27	22.7	0.71	0.11	Morph.Relation		1	PrimedLD	2	2	36	N400	330-430	0.11	0.02
Wang, W. et al.	1a	2017	16	21.1	0.71	0.13	Char.Freq		1	LD	2	1	40	N400	250-400	0.13	0.03
Wang, W. et al.	1b	2017	16	21.1	0.71	0.65	Char.Freq		1	LD	2	1	40	N400	250-400	0.61	0.04
Wang, W. et al.	1d	2017	16	21.1	0.71	0.42	Char.Freq		1	LD	2	1	40	N400	250-400	0.40	0.04
Wang, Yuling, Jiang et al.	1	2021	24	21.9	0.71	0.82	Morph.Phono	2	1	PrimedSD	2	1	120	N400	300-500	0.79	0.03
Wang, Yuling, Li, Z. et al.	1a	2024	30	23.13	0.71	0.51	Morphology	4	1	PrimedLD	2	1	55	N400	350-400	0.50	0.02
Wang, Yuling, Li, Z. et al.	1b	2024	30	23.13	0.71	0.15	Morph.Seman	3	1	PrimedLD	2	1	55	N400	350-400	0.15	0.02
Wang, Yuling, Li, Z. et al.	1c	2024	30	23.13	0.71	0.37	Morph.Ortho	1	1	PrimedLD	2	1	55	N400	350-400	0.36	0.02
Wang, Yuling, Li, Z. et al.	1d	2024	30	23.13	0.71	0.51	Morphology	4	1	PrimedLD	2	1	55	N400	350-400	0.50	0.02
Wong et al.	1e	2014	22	20	0.71	0.02	Morph.Ortho	1	2	PrimedLD	2	1	72	N400	250-400	0.02	0.02
Wong et al.	1f	2014	22	20	0.71	0.02	Morph.Phono	2	2	PrimedLD	2	1	72	N400	250-400	0.02	0.02
Wu, J. et al.	2a	2020	25	24.1	0.71	0.30	Morph.Seman	3	1	PrimedLD	1	1	46	N400	280-540	0.29	0.02
Wu, J. et al.	2b	2020	25	24.1	0.71	0.34	Morph.Ortho	1	1	PrimedLD	1	1	46	N400	280-540	0.33	0.02
Wu, J. et al.	2c	2020	25	24.1	0.71	-0.34	Morph.Phono	2	1	PrimedLD	1	1	46	N400	280-540	-0.33	0.02
Wu, J. et al.	2d	2020	25	24.1	0.71	0.45	Morphology	4	1	PrimedLD	1	1	46	N400	280-540	0.44	0.02
Wu, Y., Duan et al.	1a	2020	26	21.12	0.71	0.47	Morph.Seman	3	1	PrimedLD	2	1	40	N400	300-500	0.46	0.02
Wu, Y., Duan et al.	1b	2020	26	21.12	0.71	0.36	Morph.Seman	3	1	PrimedLD	2	1	40	N400	300-500	0.35	0.02
Wu, Y., Duan et al.	1c	2020	26	21.12	0.71	0.37	Morphology	4	1	PrimedLD	2	1	40	N400	300-500	0.35	0.02
Wu, Y., Duan et al.	1d	2020	26	21.12	0.71	0.37	Morph.Ortho	1	1	PrimedLD	2	1	40	N400	200-300	0.35	0.02
Wu, Y., Duan et al.	1e	2020	26	21.12	0.71	0.45	Morphology	4	1	PrimedLD	2	1	40	N400	300-500	0.44	0.02
Wu, Y., Duan et al.	1f	2020	26	21.12	0.71	0.11	Morph.Ortho	1	1	PrimedLD	2	1	40	N400	300-500	0.11	0.02
Wu, Y., Tsang et al.	1a	2017	24	20	0.71	0.11	Morph.Seman	3	2	PrimedLD	2	1	72	N400	250-500	0.10	0.02
Wu, Y., Tsang et al.	1b	2017	24	20	0.71	0.50	Morphology	4	2	PrimedLD	2	1	72	N400	250-500	0.48	0.03
Wu, Y., Tsang et al.	1c	2017	24	20	0.71	0.02	Morph.Ortho	1	2	PrimedLD	2	1	72	N400	250-500	0.02	0.02

Zhang, J. et al	1a	2012	26	20.2	0.71	0.60	Morphology	4	1	PrimedLD	2	1	50	N400	300-400	0.58	0.02
Zhang, J. et al	1b	2012	26	20.2	0.71	0.51	Morphology	4	1	PrimedLD	2	1	50	N400	300-400	0.49	0.02
Zhao, S. et al.	1a	2017	18	22.8	0.71	0.08	Morph.Seman	3	1	PrimedLD	1	1	40	N400	350-400	0.07	0.03
Zhao, S. et al.	1b	2017	18	22.8	0.71	0.71	Morph.Seman	3	1	PrimedLD	1	1	40	N400	350-400	0.68	0.04
Huang, H. & Lee	1a	2018	25	22.1	0.71	-0.47	Num.Mean	3	2	LD	2	1	30	N400	250–450	-0.45	0.02
Huang, H. & Lee	1b	2018	25	22.1	0.71	0.02	Num.Mean	3	2	LD	2	1	30	N400	250–450	0.02	0.02
Huang, H. & Lee	1c	2018	25	22.1	0.71	0.15	Num.Mean	3	2	LD	2	1	30	N400	250–450	0.15	0.02
Huang, H. & Lee	1d	2018	25	22.1	0.71	0.32	Num.Mean	3	2	LD	2	1	30	N400	250–450	0.31	0.02
Huang, H. et al.	1a	2011	21	21.9	0.71	0.26	Num.Mean	3	2	LD	2	1	30	N400	250–550	0.25	0.03
Huang, H. et al.	1b	2011	21	21.9	0.71	-0.37	Num.Mean	3	2	LD	2	1	30	N400	250–550	-0.36	0.03
Wei et al.	1a	2023	37	22	0.71	0.00	Trans	3	1	LD	2	1	52	N400	275-450	0.00	0.02
Wei et al.	1b	2023	37	22	0.71	-0.32	Morph.Type		1	LD	2	1	52	N400	275-450	-0.31	0.02
Wei et al.	1c	2023	37	22	0.71	-0.26	Morph.Type		1	LD	2	1	52	N400	275-450	-0.26	0.02

Note: A more detailed data file is available on the Open Science Framework. The meaning of each variable and how they were coded is available in Table S7 in Supplementary Materials 3.

Table S5

Number of Effect Sizes and Studies (in Parenthesis) for Variables Among and Across Tasks (Measured with Components Around 200 ms)

Variable	**Level**	**General**	**Lexical Decision**	**Primed Lexical Decision**	**Primed Semantic Decision**	**Reading**
Manipulation	Character Frequency	3(1)	3(1)	0	0	0
	Morpho-orthography	7(6)	0	6(5)	0	1(1)
	Morpho-phonology	3(3)	0	2(2)	1(1)	0
	Morphemic Relation	2(2)	0	2(2)	0	0
	Morpho-semantics	8(6)	0	7(5)	0	1(1)
	Morphology	10(7)	0	9(6)	0	1(1)
Writing System	Simplified	28(11)	3(1)	21(8)	1(1)	3(1)
	Traditional	5(2)	0	5(2)	0	0
Presentation	RSVP	3(1)	0	0	0	3(1)
	Isolated	3(1)	3(1)	0	0	0
	Priming	27(11)	0	26(10)	1(1)	0
Publication Language	Chinese	6(2)	0	6(2)	0	0
	English	27(11)	3(1)	20(8)	1(1)	3(1)
Publication Type	Journal	32(12)	3(1)	25(9)	1(1)	3(1)
	Others	1(1)	0	1(1)	0	0

Table S6

Number of Effect Sizes and Studies (in Parenthesis) for Variables Among and Across Tasks (Measured with Components Around 400 ms)

Variable	Level	General	Lexical Decision	Primed Lexical Decision	Primed Semantic Decision	Reading
Manipulation	Character Frequency	3(1)	3(1)	0	0	0
	Morpho-orthography	7(6)	0	6(5)	0	1(1)
	Morpho-phonology	3(3)	0	2(2)	1(1)	0
	Morphemic Relation	2(2)	0	2(2)	0	0
	Morpho-semantics	8(6)	0	7(5)	0	1(1)
	Morphology	10(7)	0	9(6)	0	1(1)
	Morpheme Type	2(1)	2(1)	0	0	0
	Number of Meanings	6(2)	6(2)	0	0	0
	Transparency	1(1)	1(1)	0	0	0
Writing System	Simplified	28(11)	3(1)	21(8)	1(1)	3(1)
	Traditional	5(2)	0	5(2)	0	0
Presentation	RSVP	3(1)	0	0	0	3(1)
	Isolated	3(1)	3(1)	0	0	0
	Priming	27(11)	0	26(10)	1(1)	0
Publication Language	Chinese	6(2)	0	6(2)	0	0
	English	27(11)	3(1)	20(8)	1(1)	3(1)
Publication Type	Journal	32(12)	3(1)	25(9)	1(1)	3(1)
	Others	1(1)	0	1(1)	0	0

Table S7

Code Book for Meta-analysis of EEG Studies

effectsize.id	Unique effect size number
articleName	Title of article
authors	Author(s) of article
exp	Serial number of the experiment in the article. When multiple effect sizes were extracted from an experiment, they were distinguished by letters.
sample.id	Unique sample number. Note: studies sharing participants but using different tasks or different manipulations were treated as different; studies reported multiple dependent effect sizes are considered part of the same sample. This cluster structure is used in later meta-regressions with RVE and in aggregation methods.
subject.id	Unique subject number
article.id	Unique article number
PubYear	Year of publication
sample.n	Sample size (when a study reports the exclusion of subjects, only record the number of subjects in the data analysis)
age	Average age of participants; NA if not reported
r	Correlation between the two conditions (estimated at 0.7091 if the value was unavailable from the article or raw data)
Cohens	Effect sizes calculated directly from the M's and SD's, t-values, F-values, or p-values
ProcessingLevel	Level of processing to which the variable mainly relates (1 = orthographic processing level; 2 = phonological processing level; 3 = semantic processing level; 4 = morphological processing level; NA = controversial)
Manipulation	Variable of constituent manipulated in the study (Char.Freq = character frequency; Cont.Divers = contextual diversity; Homoph.Dens = homophone density; Morph.Ortho = morpho-orthographic priming/preview; Morph.Phono = morpho-phonological priming/preview; Morph.Relation = morphemic relation priming; Morph.Seman = morpho-semantic priming/preview; Morph.Type = morpheme type; Morphology = morphology priming; Neigh.Size = neighborhood size; Num.Mean = number of meanings; Num.Pron = number of pronunciation; Plau = plausibility of first constituent; Stroke = number of strokes; Trans = semantic transparency)
WritingSystem	Writing system of stimulus (1 = simplified Chinese; 2 = traditional Chinese)
Task	Experimental task (LD = lexical decision; PrimedLD = primed lexical decision; Reading = natural reading)
PubLang	Publication language (1 = Chinese; 2 = English)
PubType	Publication type (1 = journal articles, 2 = other sources)
SetSize	The number of items per condition in the experiment. Coded as a continuous variable.
DV	Measurement
Time window	The time window of the average amplitude of component
yi	Hedge's g
vi	Sampling variance

Figure S1

Flowchart Illustrating the Study Screening and Selection Process for EEG Studies

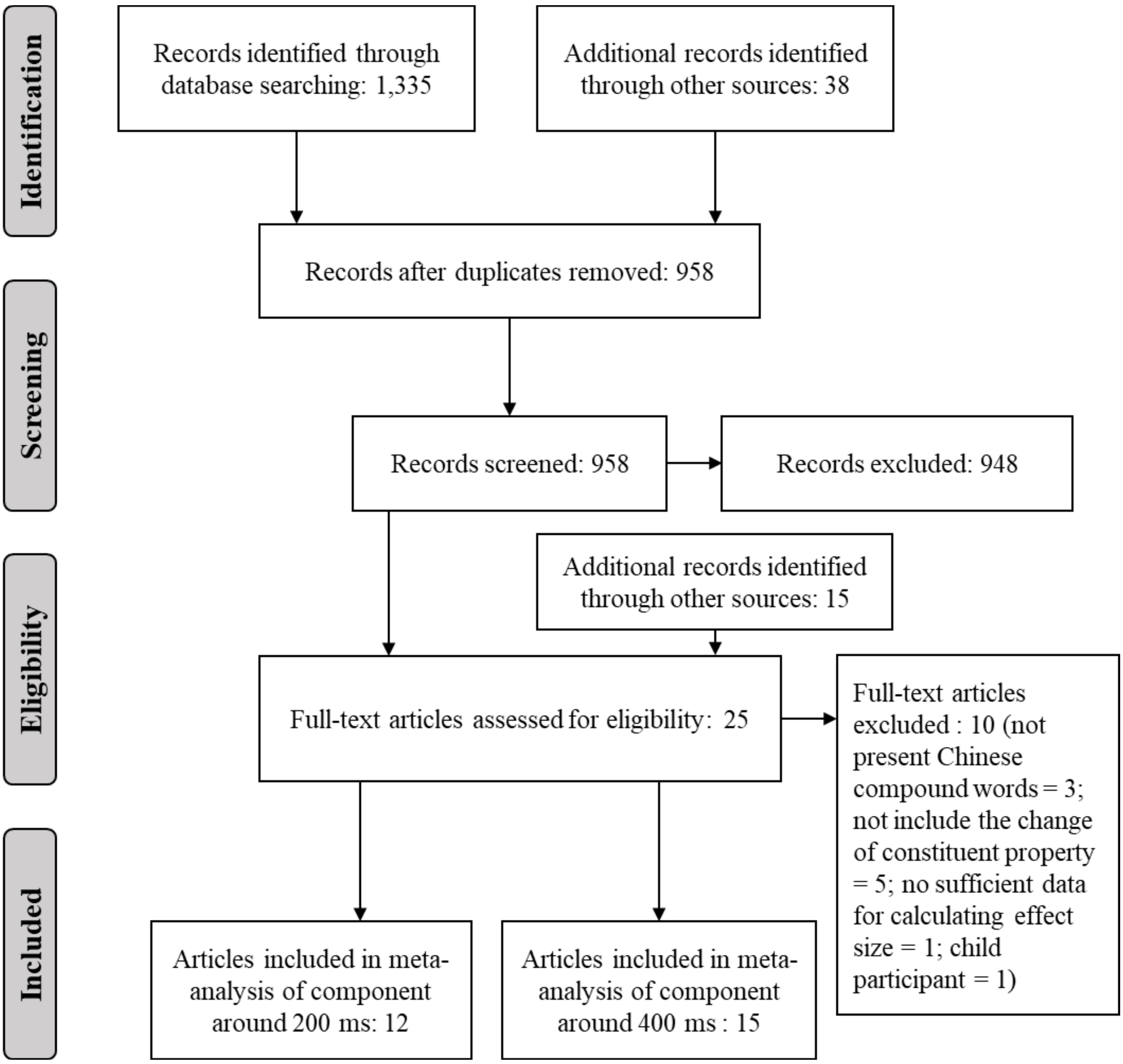
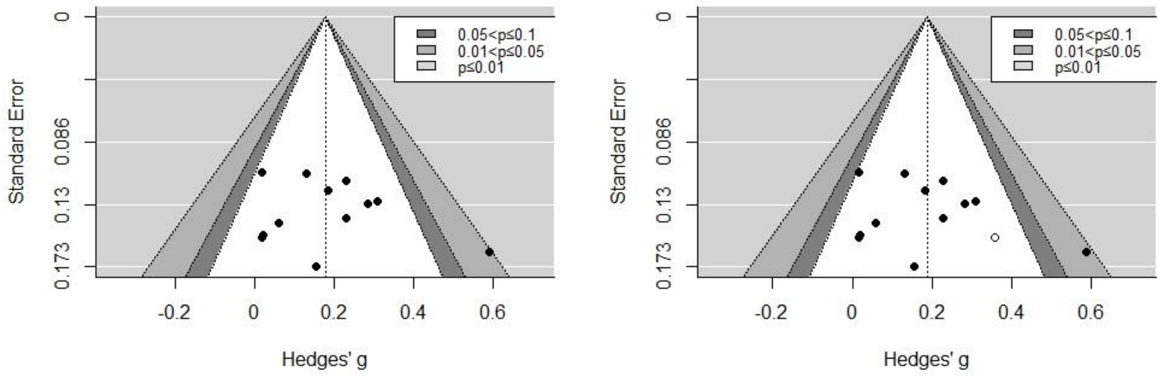


Figure S2

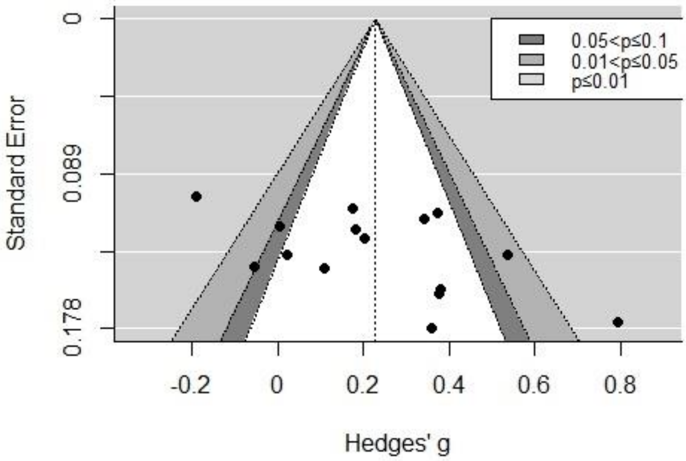
Overall Funnel Plot for Constituent-effect Studies Examining Components at ~200 ms



Note. Left panel shows the overall funnel plot for studies included in meta-analysis, examining constituent effects on Chinese compound word processing. Right panel shows the overall funnel plot after using the trim-and-fill technique; dots indicate original observed studies while hollow dots indicate filled studies (one values in the right side), with no studies being trimmed.

Figure S3

Overall Funnel Plot for Constituent-effect Studies Examining the Components at ~400 ms



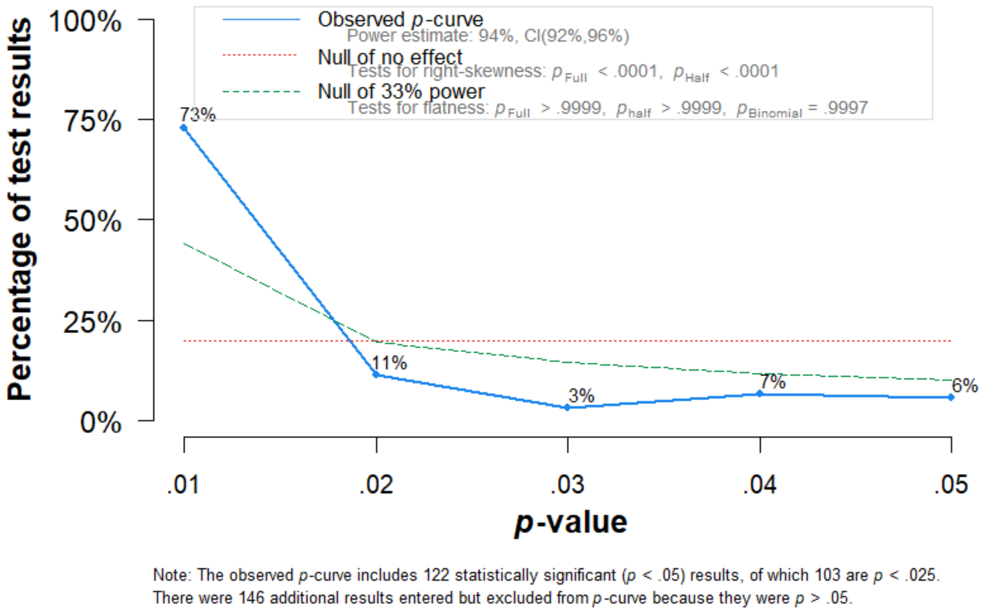
Note. Dots indicate original observed studies.

Supplementary Materials 4

P-curve analysis

Figure S4

Distribution of p *Values Under .05 for All Studies Included in the* p*-Curve Analysis*

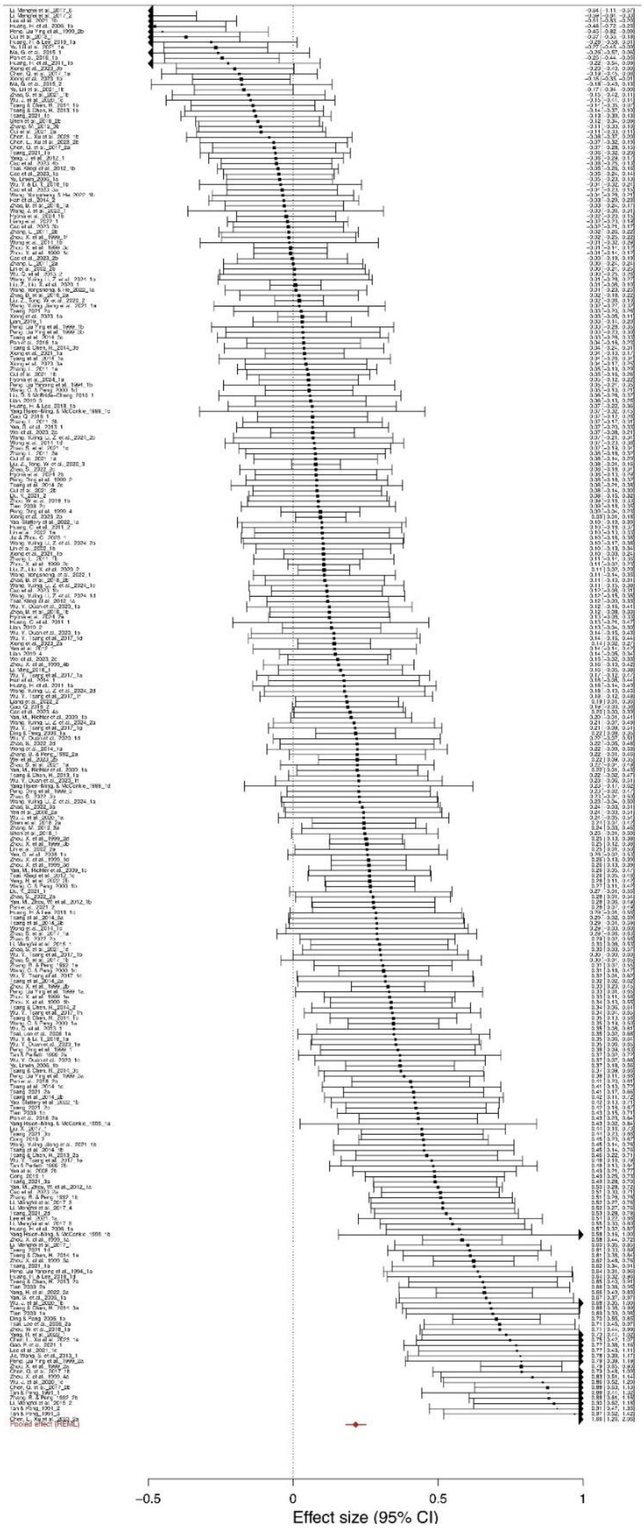


Note. The blue line shows the observed *p* curve including 122 statistically significant ($p < .05$) results, of which 103 are $p < .025$. There were 146 additional results entered but excluded from the *p* curve because they were $p > .05$. The dashed red line shows the uniform distribution of the *p* values, and the green line plots the right-skewed distribution for a power level of 33%. CI = Confidence interval.

Supplementary Materials 5

Figure S5

Forest Plot of Individual Effect Sizes of Constituent Effects



Note: The clearer format in a higher-resolution PDF is available on the Open Science Framework(https://osf.io/ywg54/?view_only=68c0aea1c4924bad88fe5bb22b32a0af).