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Morphology in Reading Comprehension Among School-Aged Readers of English: A Synthesis and Meta-Analytic Structural Equation Modeling Study

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This article synthesizes the roles of morphology in English reading acquisition and reports a meta-analytic structural equation modeling study ($k = 107$, $N = 21{,}818$) that tested the effects of morphological awareness (MA) on reading comprehension in school-aged readers. Moderator analysis was conducted through a set of subgroup comparisons based on readers' language status (monolingual vs. bilingual), age/grade (lower elementary, upper elementary, vs. middle/high school), and MA task modality (spoken vs. written). MA had significant indirect effects on reading comprehension via both word reading and vocabulary knowledge in the full sample as well as all subgroups. Its direct effect on reading comprehension, controlling for nonverbal reasoning, word reading, and vocabulary knowledge, was also significant in all subgroups except the lower elementary subgroup. Multi-group path analyses showed no significant subgroup difference in the magnitude of the direct effect of MA on reading comprehension for any moderator. However, two notable findings surfaced on the indirect effects of MA on reading comprehension: bilingual readers showed a smaller indirect effect of MA via word reading than did monolinguals; older readers showed a stronger indirect effect via vocabulary knowledge than did younger readers, whereas a converse pattern was found for the indirect effect via word reading. We conclude by pointing out the robust contribution of morphology to English reading comprehension and suggesting a strong meaning focus in morphological instruction, especially for bilingual and older school-aged readers.

Educational Impact and Implications Statement

English is characterized by an abundance of morphologically complex words, that is, words with two or more meaningful components such as affixes and roots. This means children's insights into the components and structure of these words (i.e., MA) are important for reading acquisition and development. How MA may contribute to reading comprehension has remained unclear. This meta-analysis of correlations found that MA influences reading comprehension indirectly through word reading and vocabulary knowledge, as well as directly over and above these two word-level competencies. Variations in these relations were also found between monolingual and bilingual readers of English and between children differing in age/grade. These findings suggested that morphological instruction may need to be differentiated and responsive to children's language status and stage of schooling.

Keywords: morphological awareness, word reading, vocabulary knowledge, reading comprehension, meta-analytic structural equation modeling

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Morphological awareness (MA), the ability to reflect on and manipulate morphemes (the smallest unit of meaning), has received a tremendous amount of attention in recent literature on the metalinguistic underpinnings of reading acquisition and development (Carlisle, 2003; Kuo & Anderson, 2006; Nagy et al., 2014). In addition to its importance endorsed for word reading and vocabulary acquisition, MA has also been underscored for reading comprehension (Levesque et al., 2021; Nagy et al., 2014), often based on its unique albeit small effect over and above other literacy variables. Previous findings on the morphological contribution to reading comprehension, however, have not uncommonly differed. It seems that the differences may at least be attributable to some study variations. Research syntheses are rare that aim to systematically investigate *how* morphology is involved in complex ways in reading comprehension with their covarying relations with word reading and vocabulary knowledge concurrently considered. The insights from a few existing meta-analytic studies are limited in this respect because they usually followed a univariate approach and separately analyzed the correlations of MA with individual reading variables rather than considering the complex relations between all these variables (e.g., Ke et al., 2021; J. W. Lee et al., 2022; Ruan et al. 2018).

To address this gap and explore the mechanism of morphological contribution to reading comprehension, we adopted the meta-analytic structural equation modeling (MASEM) method to conduct a meta-analysis of existing correlation-based studies that had a focus on MA and reading comprehension. MASEM combines meta-analysis and structural equation modeling (SEM) to synthesize correlation matrices and test a theory-driven model(s) based on the pooled correlation matrix (Cheung, 2015a; Cheung & Chan, 2005). We focused on school-aged readers of English and tested whether MA predicts reading comprehension over and above word reading and vocabulary knowledge (i.e., a direct route) as well as indirectly through the mediation of these two word-level literacy variables (i.e., indirect routes; see Levesque et al., 2021). We also conducted three sets of moderator analysis or subgroup comparisons using multi-group SEM (Jak & Cheung, 2018) to test how the strength of these routes may differ between native-speaking/monolingual and bilingual/second language (L2) readers of English, readers varying in age/grade (lower elementary, upper elementary, and middle/high school), and studies that varied in MA task modality (spoken vs. written). MASEM with subgroup comparisons provides a unique opportunity to explore these issues, given that individual primary studies rarely incorporated and directly compared different reader groups or task conditions.

This MASEM study also answers Carlisle's (2010) call for exploring "the way or ways morphological awareness contributes to different areas of literacy" (p. 480). Notably, exploring potential variations in the different routes (direct and indirect) across subgroups provides important theoretical insights into how MA and reading development may differ in monolingual and bilingual children and how the contribution of MA to reading may change developmentally in school-aged readers. Any differences revealed between subgroups of readers on the paths of MA to reading comprehension may inform targeted morphological instruction to boost their reading achievements, as "different approaches to morphological instruction will support some of these paths more than others" (Nagy et al., 2014, p. 6; see also Kirby & Bowers, 2017).

Morphological Contribution to Reading Comprehension: Direct and Indirect Routes

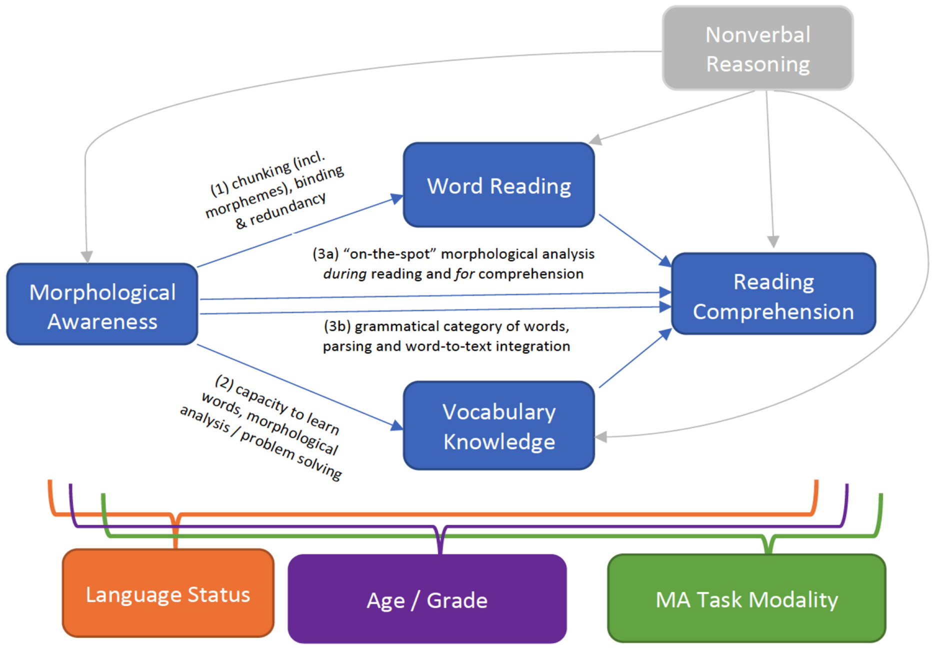
MA entails an analytic approach to morphologically complex words. It is a multidimensional and multifaceted construct that entails different types and levels of insights into morphologically complex words (Kuo & Anderson, 2006). Although MA has been endorsed as an important underpinning of reading acquisition, the extent to which different aspects are functional in the process can manifest significant variations across languages as a result of cross-linguistic variations in morphological systems and written representations of morphological information (Kuo & Anderson, 2006; J. W. Lee et al., 2022; Ruan et al., 2018). For English, the focal language of the present meta-analysis, studies on MA and reading have focused predominantly on derivation (see Table S1 in the online supplemental materials). This research emphasis does not seem surprising because derivation is not only a highly productive morphological process in English but also inherently complex. In what follows, we discuss distinct direct and indirect mechanisms of morphological contributions to English reading comprehension in light of code/form, meaning, and syntactic perspectives. These mechanisms are represented in the different paths shown in Figure 1.

Binder of Representations of Lexical Constituents, Redundancy, and Chunking (Path 1)

The lexical quality hypothesis (Perfetti, 2007), and likewise the Reading Systems Framework (Perfetti & Stafura, 2014), provides a very useful framework for understanding the code/form-based perspective on an indirect contribution of MA to reading comprehension (see also Kirby & Bowers, 2017; Levesque et al., 2021). This is shown as Path 1 in Figure 1, that is, MA → Word Reading → Reading Comprehension. For smooth comprehension to happen, words need to be recognized, and integrated, efficiently. A well-functioning word recognition system necessitates high-quality representations of lexical constituents—phonology, orthography, and semantics—and mechanisms that bind these constituents. Morphology is underscored as a "binding agent" (Kirby & Bowers, 2017) that strengthens "the links between the orthographic, phonological, and meaning representation of words and morphemes" (Nagy et al., 2014, p. 10). This function can be notably seen from derivation where suffixation modifies the meaning of a word and often the pronunciation and/or the spelling of that word as well (e.g., *decide* → *decision*). It is also often the case that suffixation changes the grammatical category of a word. The "binder" role of morphology in word reading can also be understood in light of English being a deep orthography or lacking transparency in grapheme-to-phoneme correspondences (GPC; Katz & Frost, 1992). At the smallest grain size level (phonemes), English is full of irregularities, whereas at a larger grain size level (morphemes), it is often very regular (Ziegler & Goswami, 2005). Morphology offers "islands of regularity" in English (Rastle, 2019, p. 47). For example, while *-ive* carries the pronunciation of both /iv/ (*live*) and /aiv/ (*strive*), it is consistently pronounced /iv/ when used as an adjectival suffix (*preventive*). Accordingly, high-quality representations of morphemes would suggest other well-developed and overlapping aspects of word identity, including phonological, orthographic, and semantic information of written words. The redundancy in representations of word identity information facilitates word reading (Nagy et al., 2014; Perfetti, 2007).

Figure 1

Direct and Indirect Routes of Morphological Awareness to Reading Comprehension



Note. See the online article for the color version of this figure.

Strong MA thus implies high-quality sublexical representations and adept utilization of them for word reading. Not only can morphology be an important source of information when GPC rules fail or are insufficient for *accurate* decoding of words, but the utilization of the larger-size unit can also boost decoding *fluency*. This is also in line with stage/phase models of reading acquisition where readers at a relatively late phase (e.g., the consolidated alphabetic phase in Ehri, 2005) employ chunking (e.g., syllables and morphemes) to read multisyllabic words, including multimorphemic ones. As Verhoeven and Perfetti (2011) argued, "reading more complex words may involve processes of morphological decomposition as well as grapheme-phoneme connections and whole-word look-up methods" (p. 458). Inasmuch as word reading, including morphological decoding fluency, serves as a fundamental basis of text reading and comprehension (Perfetti & Stafura, 2014; Silverman et al., 2013; Zhang & Ke, 2020), MA can perhaps be understood to contribute to reading comprehension *indirectly* through the mediation of word reading, that is, MA → Word Reading → Reading Comprehension (Deacon et al., 2014; Levesque et al., 2017, 2021; Nagy, 2007; J. Zhang et al., 2020).

Morphological Problem-Solving, Meaning Inference, and Word Learning (Paths 2 and 3a)

To probe the contribution of MA to reading comprehension, an account is also essential from a *capacity* perspective where readers are conceptualized as "morphological problem solvers." Meaning-based mechanisms, that is, Path 2 (MA → Vocabulary Knowledge → Reading Comprehension) and Path 3a (MA → Reading Comprehension) as shown in Figure 1, also play a fundamental role (Nagy et al., 2014).

Multimorphemic words are prevalent in English (especially in written texts), and new words are constantly being coined and added to the language based on morphological principles. Compared to the rather limited set of derivational affixes, derivational words in English are enormous in number and ever-expanding (Bauer & Nation, 1993; Nagy & Anderson, 1984). This fact suggests that all readers in their lifespan perhaps face a practical need to expand the lexical repertoire for reading well and to constantly deal with new words during reading. Many terms have been used to describe readers' engagement with morphological clues for dealing with those words. Anglin (1993), for example, used morphological problem-solving to describe children's use of the meanings of constituent morphemes (root and affix) to infer the meaning of an unknown word. Nagy (2007) explained the instantaneous resolution of vocabulary gaps during reading as "on-the-spot vocabulary learning" (p. 64). Levesque et al. (2021), in constructing a Morphological Pathways Framework, underscored this meaning-focused process as morphological analysis (in distinction from morphological decoding). In applied linguistics, this process is sometimes referred to as lexical inferencing (Nassaji, 2003; Zhang & Koda, 2012). Notwithstanding the different terms used, there seems to be a shared emphasis on a *capacity*- and *meaning*-oriented, analytic approach to morphology and words in text reading and comprehension. This theoretical perspective, however, still begs the question of how MA contributes to reading comprehension. It seems there are at least two distinct albeit related accounts, as described below.

First, regarding the MA → Vocabulary Knowledge → Reading Comprehension route, since vocabulary knowledge is fundamental for any reading purposes (Anderson & Freebody, 1981; see also Perfetti, 2010), any mechanism related to vocabulary development should be inherently important for reading comprehension. Readers need to possess a capacity to deal with unfamiliar words (or to be a "word detective;" Goodwin et al., 2012) and expand their vocabulary for successful reading and comprehension. MA, in light of the problem-solving mechanism, exemplifies such a capacity. It may contribute to reading comprehension *indirectly* through the mediation of vocabulary knowledge. Readers with stronger MA may be inherently better analytic word learners or problem solvers and possess a larger vocabulary (and also greater vocabulary depth, in line with a lexical quality perspective), which consequently facilitates comprehension. Many studies found that MA was a significant predictor of vocabulary knowledge and its growth in English-speaking children as well as bilingual readers of English (e.g., Kieffer & Lesaux, 2012; McBride-Chang et al., 2005; Zhang et al., 2016).

Second, during the reading of any text where unknown morphologically complex words are present, readers face a need to negotiate choices for dealing with those words. They may resolve vocabulary gaps *in situ* through morphological analysis (particularly when other clues such as discourse context are unavailable or unhelpful) so that any barrier to comprehension can be removed. This mechanism, which is shown as Path 3a (MA → Reading Comprehension) in Figure 1, implies that readers with stronger MA tend to be better "on-the-spot" problem solvers. It entails the direct application of MA to tackle immediate lexical (and comprehension) needs that emerge during reading. It is also related to the first account in that constant and active morphological problem-solving during reading could result in vocabulary acquisition and expansion, that is, initially unknown words eventually becoming part of the lexical memory, even though the reading may not necessarily involve any explicit goal of the reader for word learning. This account seems to be in line with the path from comprehension processes to lexicon (where morphology is an important component) in the Reading System Framework (Perfetti & Stafura, 2014) and also well supported by the literature on reading, incidental learning of words, and vocabulary acquisition (Nagy & Scott, 2000). This mechanism, while also underpinned by morphological analysis, is distinct from the indirect mechanism described above, that is, the MA → Vocabulary Knowledge → Reading Comprehension route, because it is contingent, ad hoc, and strategic for the immediate reading task or emerging comprehension needs rather than for explicit vocabulary learning and expansion purposes. We call this mechanism a contingent, *direct* route (relative to the indirect routes we have explained so far).

Suffixation, Grammatical Category of Words, and Syntactic Parsing (Path 3b)

Derivational suffixation commonly modifies the grammatical category of a word. For example, adding the verbal suffix *-ize* changes the adjective *modern* to the verb *modernize*. This property of derivation is a specific focus of the affix choice task where readers select a derivative from several choices that share the same real or pseudo base to fill up a sentence (e.g., Nagy et al., 2006; Singson et al., 2000). MA pertaining to this syntactic aspect is also related to the distributional properties of derivation in which suffixes combine with stems in principled ways (Kuo & Anderson, 2006). For example, *darkness* is a real/legitimate derivative in English, whereas **jumpness* is not, because *-ness*, a nominal suffix, requires to be combined with an adjective to generate a noun. Compared with MA facets focused on structural insights such as morphological segmentation (e.g., an ability to segment *affordable* into *afford* and *-able*), this syntactic aspect can be particularly challenging, especially to young or L2 English readers (Nagy et al., 2006; Sasao & Webb, 2017; Tyler & Nagy, 1989, 1990).

Compared to the code/form- and meaning-based perspectives discussed earlier, the syntactic aspect of morphology is perhaps the least studied yet can play a role that should not be ignored (Nagy et al., 2014). Nagy et al. (1993) found that English-speaking middle schoolers, while demonstrating an ability to use morphological analysis to define unknown derivational words, sometimes failed to include the syntactic or word class information encoded in suffixes to generate precise meaning interpretations. In this respect, inadequate awareness of the syntactic aspects of derivation may constrain the capacity for morphological problem-solving. Nagy (2007) also underscored how the syntactic aspect of MA may facilitate the parsing of sentences during text reading. Nagy et al. (2014) further noted that this insight may be particularly important for understanding academic texts where derivation is common for grammatical metaphors such as nominalization (see also Nagy & Townsend, 2012). With reference to the Reading Systems Framework (Perfetti & Stafura, 2014), this aspect of MA, in light of its facilitation on parsing, may contribute to word-to-text integration where identified words in the word recognition system are fed into the comprehension system for mental model construction. This connection of MA with parsing and language comprehension also seems to explain the direct route that Levesque et al. (2021) aimed to establish, in their Morphological Pathways Framework, between the linguistic system and the text comprehension processes component of the Reading Systems Framework. Accordingly, we have added this syntactic mechanism as a *direct* route in Figure 1, that is, Path 3b/MA → Reading Comprehension, to show another way MA influences reading comprehension over and above word reading and vocabulary knowledge.

Moderators

MASEM studies usually involve a small set of moderators, because they focus on testing theory-driven models that involve complex relations between variables (Cheung, 2015a, 2021). Existing MASEM studies on reading (e.g., Hjetland et al., 2020; H. Lee et al., 2022; Peng et al., 2021) usually included no more than three moderators. This study identified three moderators for the rationale explained below, including language status, age/grade, and MA task modality.

Language Status

Readers of English can differ significantly in their language background and related socio-educational history. How MA develops and how it supports reading acquisition can differ between native-speaking/monolingual and bilingual/L2 learners. Monolinguals grew up speaking English at home and have overall developed an oral language foundation (oral vocabulary and language comprehension) before formal learning to read commences in elementary school. L2 readers/bilingual children, in contrast, typically do not become literate in English following a route where oral language proficiency is initially developed and brought into schooling where reading skills are formally taught (August & Shanahan, 2006; Bratlie et al., 2022; Melby-Lervåg & Lervåg, 2014). A typical characteristic of L2 reading, compared to monolingual reading, is that children usually lack early exposure and, as a result, generally have less exposure to the target language. In a foreign language context (i.e., English not being a societal language), early English exposure can be minimal and English *language* and *reading* acquisition happen concurrently, relying predominantly on limited classroom instruction. The constrained oral language exposure, and often print experience as well, can heavily influence L2 learners' development of reading as well as component skills that support reading comprehension (e.g., MA; August & Shanahan, 2006; Melby-Lervåg & Lervåg, 2014). To add to the complexity of these group differences, monolingual and bilingual readers may also differ in social-economic profiles (e.g., parental education, family income, and home environment for education), which could significantly impact English language and literacy development and have far-reaching ramifications on school achievement (Hoff, 2013; Kieffer, 2008, 2010; Luo et al., 2021). In the United States, for example, bilingual children or language-minority students tend to come from low-income families, and this socioeconomic status (SES) affects their early access to English and subsequently the growth trajectories in English reading (Kieffer, 2008).

All the direct and indirect paths in Figure 1 may differ between monolingual and bilingual readers. Bilingual children's constrained access to English could significantly impact their development of morphological representations (roots and affixes) as well as the representations of phonological and semantic aspects of English words (i.e., input-driven learning where frequency shapes linguistic knowledge and skills; Ellis, 2002). Compared to monolinguals, bilinguals' quality of lexical and sublexical representations in terms of both precision and redundancy, and accordingly MA, could be weaker (Bratlie et al., 2022), and as a result, they may not be as actively reliant on morphological processes such as chunking or utilizing morphemes as a larger-size unit for word reading. Likewise, bilinguals' shallow morphological representations may also affect their capacity to conduct morphological analysis (Bratlie et al., 2022; Clahsen & Felser, 2018). Constrained English exposure may, in a similar vein, suggest reduced processing of suffixation or attention to the grammatical roles suffixed words play in texts. Consequently, the syntactic function of MA for supporting parsing and comprehension may also be affected. Over and beyond these paths that directly involve morphology, the (relative) contributions of word reading and vocabulary knowledge to reading comprehension may also vary between the two groups. Whereas for monolinguals word reading and vocabulary may be of similar importance in text reading, bilinguals (especially learners of English as a foreign language) may show a more salient reliance on vocabulary (Jeon & Yamashita, 2014; Pasquarella et al., 2012). Consequently, the two groups may also differ in the indirect effect of MA on reading comprehension via word reading and/or vocabulary knowledge.

Age/Grade

Reading and its subskills develop over time. Increased linguistic processing and literacy experience over school years promote the development of reading abilities as well as metalinguistic insights that support reading development. As a result, MA and its associations with reading and comprehension may show notable differences across grades or school stages.

First, developmental differences in MA may impact the MA → Word Reading → Reading Comprehension route. According to phase/stage models of reading acquisition (e.g., Ehri, 2005), chunking, including the utilization of morphemes, for word reading appears relatively late. In terms of lexical quality, the extent to which morphology functions as a binding agent, improving precision and adding to redundancy in sublexical representations, affects word reading (Nagy et al., 2014). Older readers' more developed MA thus suggests stronger word reading skills. Studies testing the simple view of reading (e.g., Ouellette & Beers, 2010) suggested that the contribution of decoding to reading comprehension, in comparison to that of language comprehension (vocabulary and listening comprehension), becomes less salient in older children, possibly because decoding is a relatively constrained skill and shows an asymptotic pattern of development (Paris, 2005). These findings, taken together, seem to paint a complex picture of the indirect route via word reading. On the one hand, MA may show a more salient role in word reading over time; on the other hand, the importance of word reading, particularly decoding accuracy, in reading comprehension may diminish developmentally.

Second, as MA develops over time, children's capacity for morphological problem-solving may also have strengthened. This enhanced capacity, together with greater knowledge of roots and affixes (i.e., morphemic knowledge), facilitates vocabulary expansion. Morphological analysis is a major mechanism that accounts for vocabulary growth across school years (Anglin, 1993; Nagy & Anderson, 1984). Anglin (1993) found that fifth-grade English-speaking children used morphological problem-solving more extensively and effectively than did their younger peers. MA may thus play an increasingly more important role in reading comprehension over time. In other words, the meaning-oriented routes (e.g., MA → Vocabulary Knowledge → Reading Comprehension) may presumably be stronger in older readers.

Finally, from a syntactic perspective, the effect of MA on reading comprehension (Path 3b in Figure 1) may become stronger over time as well. Older children have stronger sensitivity to the grammatical function of English suffixes, such as discrimination of the grammatical categories of suffixed words and morphological constructions (Carlisle, 2000; Nagy et al., 2006; Singson et al., 2000). They are also much better at judging the combinability of roots and suffixes, showing stronger insights into the distributional properties of English suffixation (Zhang, 2017). Children hypothetically become more adept at using the grammatical information of suffixed words for sentence parsing and text comprehension over school years. Developmentally, an increasing role of the syntactic aspect of MA in reading comprehension also seems in line with the fact that school texts become linguistically more complex (Nagy & Townsend, 2012).

MA Task Modality

MA tasks may be administered under different conditions, showing between-study heterogeneity. They may be written-based such that children read task items and circle answers or respond in writing. Alternatively, they could be administered orally with items read aloud to children and children verbalizing answers, or children have access to both written and spoken language (e.g., they work on a written task with the stimuli also read aloud to them).

The inclusion of spoken language in the last two scenarios is typically intended to avoid or reduce the demand for written language processing, notably word decoding. In other words, whether spoken language is involved in MA tasks may affect the correlation between

MA and word reading and, consequently, the indirect effect of MA on reading comprehension, that is, MA → Word Reading → Reading Comprehension. Hypothetically, the effect would be smaller with spoken MA tasks than those that are written-based. MA task modality might also affect the correlation of MA with vocabulary knowledge, and consequently the MA → Vocabulary Knowledge → Reading Comprehension route as well, given that vocabulary knowledge is often measured as an oral language competence in school-aged children (see Table S1 in the online supplemental materials). It is therefore of relevance to test MA task modality as a moderator of the routes shown in Figure 1.

Previous Meta-Analytic Studies on Morphology and Reading

As primary research evidence has accumulated on the importance of morphology in reading, meta-analytic studies have also been conducted. Bratlie et al. (2022) compared morphological knowledge in language-majority and language-minority students. Ruan et al. (2018) compared the correlations of phonological awareness (PA) and MA with reading accuracy, fluency, and comprehension in Chinese and English. Ke et al. (2021) focused on the correlations between first language (L1) and L2 MA and those between L1 and L2 MA with L2 word decoding and reading comprehension, in bilingual readers. J. W. Lee et al. (2022) meta-analyzed the correlations of MA with a range of literacy-related skills (e.g., PA, vocabulary, word reading, text reading fluency, and reading comprehension) and in a range of languages (e.g., Arabic, Chinese, English, Hebrew, Korean, and Spanish). MA was also included as a correlate of reading comprehension in the meta-analysis of struggling adult readers of English (Tighe & Schatschneider, 2016) or L2 readers (Jeon & Yamashita, 2014). Meta-analysis was also conducted on the effects of morphological instruction (e.g., Bowers et al., 2010; Goodwin & Ahn, 2010, 2013).

These meta-analyses, nevertheless, showed limitations, a notable one of which is common to univariate methods of meta-analysis. Univariate meta-analysis, despite being common in the literature, demonstrates a few notable weaknesses (Cheung, 2015a, 2021; Jak, 2015). For example, the correlation meta-analyzed between two variables fails to consider these variables' covarying relations with other variables within a study. The coefficients in a correlation matrix are treated as if they were independent. In a meta-analysis of treatment effects, multiple outcomes are often included but their potential relations are usually not considered. A lack of attention to the covarying relations of MA and reading comprehension with word reading and vocabulary knowledge seems to obscure some meta-analytic findings on morphological instruction. For example, as opposed to some "lower-level" outcomes such as decoding, the effect was sometimes very small and not significant for reading comprehension (Goodwin & Ahn, 2013). This may raise an interesting question: could this be related to a lack of any direct effect of MA on reading comprehension or the effect being fully mediated by word reading and/or vocabulary knowledge? Meta-analytic findings on the distinct routes discussed earlier of MA will shed light on questions like this and help understand why existing morphological interventions, depending on the route(s) of their instructional focus (e.g., chunking for decoding and/or morphological problem-solving), varied in the magnitude of the effect on reading comprehension. MASEM, in this respect, is much needed because it combines meta-analysis and SEM to test theory-driven models on the effects of MA on reading comprehension, with concurrent consideration of other related variables and based on a pooled correlation matrix (Cheung, 2015a, 2021).

Goals of This Meta-Analysis and Research Questions

Previous meta-analyses have not tested how MA is related to reading comprehension with concurrent consideration of these two skills' covarying relations with other literacy skills. Primary research studies often were unable to test how the effects of MA on reading comprehension may differ, depending on reader and task-related factors. This MASEM study set out to fill the gap by testing the direct and indirect effects of MA on reading comprehension in school-aged readers of English. The following two sets of research questions guided this meta-analysis.

1. Does MA predict reading comprehension over and above word reading and vocabulary knowledge (i.e., a direct effect)? Do word reading and/or vocabulary knowledge mediate the contribution of MA to reading comprehension (i.e., an indirect effect)?
2. Do the direct and indirect effects of MA on reading comprehension differ in magnitude based on readers' language status, age/grade, and MA task modality?

Method

Literature Search and Inclusion and Exclusion Criteria

This study was part of a larger meta-analytic project on MA and reading comprehension across languages, contexts, and reader groups. For that project, two sets of keywords were created and used in combination ("AND") for literature searches. The first set focused on morphology and included *morphology, morphemes, morphemic, MA, morphological knowledge,* "OR" *morphological analysis*. The second set focused on reading comprehension and included *reading comprehension, text comprehension, text reading, sentence comprehension,* "OR" *passage comprehension*. We restricted the searches to outputs presented in English from 1981 to 2020 and to refereed journals.

Initial searches were conducted on three databases: APA PsycInfo ($n = 3{,}684$), Linguistics and Language Behavior Abstracts ($n = 2{,}813$), and Educational Resource Information Center ($n = 349$; n refers to the number of articles). These were supplemented by additional searches on the Web of Science and Google Scholar and by checking the lists of included studies in previous meta-analyses of correlations (e.g., Ke et al., 2021; Ruan et al., 2018). The search results were initially screened by checking the title and abstract of each article. Outputs that were not primary empirical studies, such as narrative reviews, previous research syntheses, or editorials, were excluded. The entries that remained were further screened, based on careful reading of the full text of each article, by the first author and then checked by the second author against the following two criteria.

First, studies must include measures that assessed MA and reading comprehension. Reading comprehension was defined as any measure that involved readers' understanding of meaning units larger than words including sentences or passages. A measure was considered to measure MA if it touched on readers' ability to reflect on and manipulate morphemes and their sensitivity to the morphological structure of words (see Appendix S1 in the online supplemental materials). Studies focused on morphological processing or tacit knowledge of morphology without any measure of MA were excluded.

Second, the correlation between MA and reading comprehension must be reported. Intervention studies that measured MA and reading comprehension but did not report their correlation were excluded. A restricted approach was not adopted that required a study to also include correlations with word reading and/or vocabulary knowledge. A notable advantage of MASEM is that the correlations between any two variables from any primary studies can be meta-analyzed to form a pooled correlation matrix. A full correlation matrix with all variables of the synthesis interest is not required for any individual primary study.

As a result, 171 articles were identified ($n = 151$ from the initial searches and $n = 20$ from the supplementary searches) from the larger meta-analytic project. For the focus of the present meta-analysis on English, those articles were further screened against an additional criterion, that is, the correlation between *English* MA and *English* reading comprehension must be reported. For studies that examined bilinguals' two languages, correlations in both languages were extracted for the meta-analytic project, but only those in English were included for the present meta-analysis. Studies that did not focus on school-aged students (defined as k-12 students or aged 18 or younger) were excluded. Also excluded were those focused on students with learning disabilities or special education needs. Eventually, 73 articles were selected with 107 effect sizes (i.e., independent correlation matrices based on separate study samples). Figure 2 presents a flow chart that illustrates the article search, screening, and selection process.

Coding Procedures and Interrater Reliability

We identified and extracted correlation matrices, sample sizes, and the three moderators (i.e., language status, age/grade, and MA task modality), together with a few other study features, such as study context; structure of MA tasks; as well as actual measures for MA, word reading, vocabulary knowledge, and reading comprehension. In what follows, we briefly describe how coding was conducted for the proper extraction of correlation matrices and for each moderator. Further details on coding can be found in Appendix S1 in the online supplemental materials, which also provides the definition for each variable that guided the selection and screening of studies and the coding process. Table S1 in the online supplemental materials presents the coding results and also serves as the dataset for this meta-analysis.

The coding of correlations involved the five variables shown in Figure 1. Nonverbal reasoning was coded as a general cognition variable and included as a covariate that predicted MA, word reading, vocabulary knowledge, and reading comprehension. If there were multiple measures for any variable that resulted in more than one correlation of this variable with other ones, we averaged the coefficients (see Ke et al., 2021; Peng et al., 2021). For longitudinal studies, we extracted the correlation(s) based on the first wave (Ke et al., 2021), which also enabled us to boost the size of the lower elementary subgroup. Occasional exceptions that required more nuanced coding are presented in Appendix S1 in the online supplemental materials.

Language status was coded as monolingual ($k = 60$) or bilingual ($k = 46$). For most of the included studies, this coding was straightforward because participants are described to be (a) native speakers of English; or (b) bilingual or language-minority students in an English-speaking society (e.g., the United States or Canada) or studying English in a bilingual or foreign language context (e.g., China, South Korea, or Singapore). More nuanced coding decisions were involved in a small number of studies where participants were a mixed sample (see Appendix S1 in the online supplemental materials).

The coding of age/grade largely followed previous meta-analyses of morphology and reading (Goodwin & Ahn, 2013; Ke et al., 2021). Specifically, the following codes were applied. Middle and high school grades were combined (see also J. W. Lee et al., 2022; Ruan et al., 2018), because only six studies focused on high school students.

- lower elementary ($k = 13$): grade 2 or below (8 years old or younger)
- upper elementary ($k = 47$): grades 3–5 (9–11 years old)
- middle/high school ($k = 46$): grades 6–12 (12–18 years old).

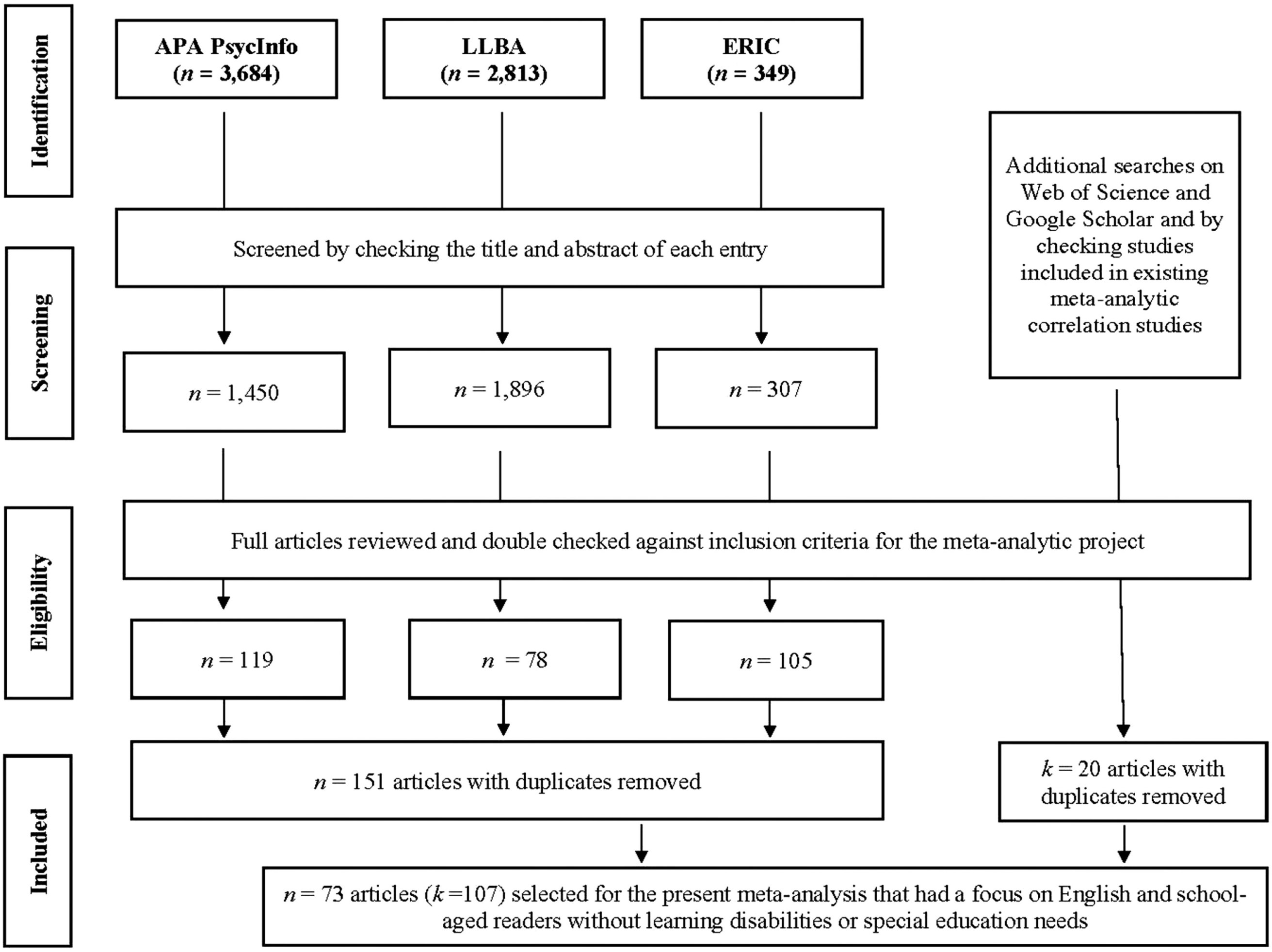
MA task modality was coded as whether spoken language is involved in task administration. "Yes" refers to where MA tasks are oral-based or are administered in the written form but also involve spoken language (e.g., written stimuli read aloud to participants). "No" refers to where MA tasks are completely written-based.

The first two authors constructed and agreed on the codes and the coding process based on initial reading of all the included studies. They independently coded a random sample of 18 studies, or 25% of the included studies, with 26 independent correlation matrices. For 23 of these correlation matrices, there was a full match between the two coders. For the coding of individual correlations, Cohen's $\kappa = 0.937$ ($p < .001$), showing a strong inter-coder agreement. There was also full agreement on the coding of all moderators. The two coders subsequently discussed their results on the three correlation matrices and resolved any inconsistencies in understanding and applications of the codes, and then each coded half of the rest of the studies and swapped to check. Any further issues were discussed and resolved through regular meetings.

Missing Variables and Correlations

Not all included studies enabled the extraction of a full correlation matrix involving all five variables. Anything missing in a correlation matrix is coded as NA for MASEM analysis (see Table S1 in the online supplemental materials). A lack of measurements for variables other than MA and reading comprehensions in a primary study would result in missing variables. Among the 107 effect sizes, 12 were a full correlation matrix and 95 had missing variables. In the latter case, nonverbal intelligence, for example, was not measured in a large number of the included studies ($k = 89$). Seven of the 95 effect sizes with missing variables also showed missing correlations; that is, one or more correlations were not reported for the measured variables. Ku and Anderson (2003), for example, measured MA, vocabulary knowledge, and reading comprehension, but only reported the correlations of MA with vocabulary knowledge and reading comprehension; the correlation between the latter two variables was not reported. Missing variables and correlations were

Figure 2
A Flowchart Showing the Process of Searching, Screening, and Selecting Articles



Note. n refers to the number of articles, whereas k refers to that of independent effect sizes or correlation matrices based on independent study samples. An article may include more than one independent sample with more than one correlation matrix.

handled through the full-information maximum likelihood (FIML) estimation method in Stage 1 of Two-Stage Structural Equation Modeling (TSSEM) to pool correlation matrices (Cheung, 2015a, 2021).

Procedure of Meta-Analysis and TSSEM

The primary goal of this MASEM study was to test a theory-driven model on the direct and indirect effects of MA on reading comprehension with concurrent consideration of word reading and vocabulary knowledge based on pooled correlation matrices, rather than to separately meta-analyze each correlation between any two variables, which was the focus of existing univariate meta-analyses on MA and reading (Ke et al., 2021; J. W. Lee et al., 2022; Ruan et al., 2018). Nevertheless, following Hjetland et al. (2020), we also conducted univariate meta-analyses, hoping that the results may be useful to interested readers. All univariate analyses were conducted using Comprehensive Meta-analysis Software (Borenstein et al., 2006).

For MASEM, we adopted the TSSEM method (Cheung, 2015a, 2021; Cheung & Chan, 2005; Jak, 2015). In Stage 1, TSSEM considers the dependence of correlations in a matrix and pools correlation matrixes using the FIML estimation method, which handles data missing at random without bias and is a preferred choice. In Stage 2, a theory-driven model(s) of the researcher's interest is then fitted to the pooled correlation matrix based on the weighted least squares estimation method. The present meta-analysis aimed to test the path model shown in Figure 1 based on random-effects models, which assume that studies have their own population effect sizes (Cheung, 2015a, 2021).

All the MASEM analyses were conducted using the metaSEM package (Cheung, 2015b), which utilizes the OpenMx package (Neale et al., 2016) and runs in the R environment (R Core Team, 2021). TSSEM was first run on the full sample (see Case 2 in Jak & Cheung, 2018). An indirect effect of MA on reading comprehension, such as MA → Word Reading → Reading Comprehension, was directly estimated in metaSEM based on the product of the component effects. This was followed by three sets of subgroup analyses based on the three moderators (see Case 4 in Jak & Cheung, 2018). For each moderator, a separate TSSEM was conducted for a subgroup to test the study-level heterogeneity and pool correlation matrices (Stage 1) and test the direct and indirect effects (Stage 2). Multi-group path analysis was then conducted to test whether path coefficients differed significantly in magnitude between any two subgroups.[1] Functions for multi-group analysis were, at the time of this study, unavailable in metaSEM. So, the function developed by Suzanne Jak was used (http://www.suzannejak.nl/subgroup.functions.R; for an illustration, see Jak & Cheung, 2018).

Transparency and Openness

We have reported the criteria and procedure for selecting and excluding primary studies for this meta-analysis. The coding process has also been described with further details presented in Appendix S1 in the online supplemental materials. The data analytic procedure has also been clearly reported. The dataset with features coded of included studies for this meta-analysis (Table S1 in the online supplemental materials) and other supplemental materials of this article (Appendices S1–S3, Tables S2–S7 in the online supplemental materials, and R codes for the MASEM analyses) are available at https://osf.io/jq72s. This study was not preregistered.

Results

Univariate Meta-Analysis

Table S2 in the online supplemental materials summarizes the number of effect sizes and the sample size for each correlation. Table S3 and Appendix S2 in the online supplemental materials, respectively, show the mean correlations and the heterogeneity test results based on random-effects models and the forest plots for the 10 correlations between the five variables. The funnel plots in Appendix S3 in the online supplemental materials are symmetric, which indicate no retrieval bias. Tables S4a–j in the online supplemental materials show the univariate results of the moderator analysis on each correlation.

TSSEM Analysis for the Whole Sample

Table 1 shows the results of Stage 1 analysis for the whole sample ($k = 107$, $N = 21{,}818$). All correlations were significant (all $ps < .001$), ranging from 0.416 to 0.577 between the four literacy variables. The correlation of MA with reading comprehension was 0.536 (95% confidence interval [CI] [.513, .559]), which was very close to that in Ruan et al. (2018) for English MA and reading comprehension ($r = .534$) and that in J. W. Lee et al. (2022) averaged across a range of languages ($r = .54$). Significant heterogeneity was found in correlation matrices, $Q(497) = 1{,}839.492$, $p < .001$. It was also found in the correlations between any two variables except that between nonverbal reasoning and vocabulary knowledge. For the correlations between the four literacy variables, I^2 (proportion of study-level variance) was moderate or high, ranging from 0.575 to 0.811 (Higgins et al., 2003: 25% low, 50% moderate, 75% high). For the correlation between MA and reading comprehension, $\tau^2 = 0.010$, $z = 5.418$, $p < .001$ and $I^2 = 0.811$, suggesting high variability in the included studies.

In Stage 2, the pooled correlation matrix was fitted to the path model shown in Figure 1. The model showed very good model fits: $\chi^2(1) = 34.537$, $p < .001$; comparative fit index (CFI) = 0.994, root mean square error of approximation (RMSEA) = 0.039 (95% CI [.029, .051]), standardized root mean square residual (SRMR) = 0.033. As Table 2 shows, MA significantly predicted word reading and vocabulary knowledge, controlling for nonverbal reasoning, $\beta = .512$ [.469, .556] and $\beta = .511$ [.478, .544], respectively. MA, word reading, and vocabulary knowledge were each a significant and unique predictor of reading comprehension. For the direct effect of MA on reading comprehension over and above word reading and vocabulary knowledge, $\beta = .146$ [.082, .208]. The indirect effects of MA on reading comprehension were also significant: $\beta = .140$ [.105, .177] and $\beta = .190$ [.160, .221] for the routes via word reading and vocabulary knowledge, respectively. Thus, the effects of MA on reading comprehension were partially mediated by word reading and vocabulary knowledge.

Subgroup Comparisons Based on Language Status

Separate TSSEM analysis was conducted for the bilingual ($k = 46$; $N = 5{,}423$) and monolingual ($k = 60$; $N = 16{,}084$) subgroups, followed by comparisons of the magnitude of the path coefficients between these two subgroups through multi-group path analysis. Tables S5a and b in the online supplemental materials show the Stage 1 analysis results for the two subgroups, respectively. For Stage 2 analysis, the model showed good model fits for both subgroups: $\chi^2(1) = 15.733$, $p < .001$; CFI = 0.994, RMSEA = 0.052 (95% CI [.032, .076]), SRMR = 0.065 for bilinguals and $\chi^2(1) = 15.792$, $p < .001$; CFI = 0.996, RMSEA = 0.030 [.018, .044], SRMR = 0.027 for monolinguals.

[1] The one-stage approach is a recent development of MASEM (Jak & Cheung, 2020). In comparison to the two-stage approach, that is, TSSEM, the one-stage approach shows two advantages. First, moderators can be directly fit into an SEM model, explaining study variations in parameters such as path coefficients; second, they can be continuous. Despite these strengths, we decided to adopt TSSEM based on the purpose of the present study.

First, while the one-stage approach could test how a moderator such as language status (through a dummy coded categorical predictor) may predict the path coefficients in Figure 1, without follow-up analysis, the magnitude of specific effects, including the indirect effects of MA on reading comprehension, would be unknown for the subgroups of a moderator. Knowing the actual coefficients (standardized coefficients also represent the magnitude of effects) in subgroups can be theoretically important and also shed light on instruction. In addition, the one-stage approach alone without subgroup comparisons would not enable comparing the magnitude of any indirect effect, an important focus of the present study.

Second, while age/grade, one of the moderators of the present study, may be continuous, it could not always be coded as such. In primary studies, the age reported by participants typically represents the average of the sample rather than the actual age of each participant. Phase/stage-based accounts of reading development (e.g., Ehri, 2005) tend to emphasize "qualitative" variations across distinct developmental stages rather than "quantitative" differences as a function of children's actual age or specific grade. At present, there does not seem to be any theorization of how age may function as a continuous variable that explains study-level variations in correlations between reading-related variables. This is perhaps a reason that in existing meta-analyses on reading (e.g., Jeon & Yamashita, 2014; Melby-Lervåg & Lervåg, 2014; Peng et al., 2021), including those specifically focused on MA (e.g., Goodwin & Ahn, 2013; Ke et al., 2021; J. W. Lee et al. 2022; Ruan et al., 2018), age has been largely coded to represent broad, distinct "phases" and analyzed as such in moderator analysis.

Table 1

Estimates of Correlation Coefficients and Heterogeneity Indexes Based on Stage 1 TSSEM Analysis for the Whole Sample

Variables	NVR	MA	WR	VK
MA	$r = .336$ [.278, .394], $z = 11.376$ ($p < .001$); $\tau^2 = 0.008$, $z = 1.879$ ($p = .060$); $I^2 = 0.631$	—		
WR	$r = .289$ [.222, .355], $z = 8.484$ ($p < .001$); $\tau^2 = 0.009$, $z = 1.704$ ($p = .088$); $I^2 = 0.657$	$r = .533$ [.500, .567], $z = 31.326$ ($p < .001$); $\tau^2 = 0.012$, $z = 3.932$ ($p < .001$); $I^2 = 0.745$	—	
VK	$r = .304$ [.262, .345], $z = 14.366$ ($p < .001$); $\tau^2 = 0.000$, $z = 0.000$ ($p = 1.000$); $I^2 = 0.000$	$r = .540$ [.513, .567], $z = 39.418$ ($p < .001$); $\tau^2 = 0.007$, $z = 3.548$ ($p < .001$) $I^2 = 0.633$	$r = .416$ [.385, .447], $z = 26.226$ ($p < .001$); $\tau^2 = 0.006$, $z = 2.645$ ($p = .008$); $I^2 = 0.575$	—
RC	$r = .349$ [.299, .398], $z = 13.865$ ($p < .001$); $\tau^2 = 0.004$, $z = 1.287$ ($p = .198$); $I^2 = 0.441$	$r = .536$ [.513, .559], $z = 45.529$ ($p < .001$); $\tau^2 = 0.010$, $z = 5.148$ ($p < .001$); $I^2 = 0.811$	$r = .517$ [.479, .556], $z = 26.569$ ($p < .001$); $\tau^2 = 0.017$, $z = 4.215$ ($p < .001$); $I^2 = 0.799$	$r = .577$ [.546, .608], $z = 36.632$ ($p < .001$); $\tau^2 = 0.010$, $z = 3.670$ ($p < .001$); $I^2 = 0.703$

Note. NVR = nonverbal reasoning; MA = morphological awareness; WR = word reading; VK = vocabulary knowledge; RC = reading comprehension.

As shown in Table 3, all direct and indirect effects were significant for both subgroups except that of nonverbal reasoning on reading comprehension for the bilingual subgroup. For bilinguals, controlling for nonverbal intelligence, MA significantly predicted word reading (β = .486; [.420, .546]) and vocabulary knowledge (β = .494; [.450, .537]). The direct effect of MA on reading comprehension was also significant, β = .201 [.120, .285]. Both indirect effects of MA were significant as well: β = .077 [.027, .125] via word reading and β = .188 [.153, .226] via vocabulary knowledge. For monolinguals, MA also significantly predicted word reading (β = .527; [.463, .590]) and vocabulary knowledge (β = .534; [.480, .588]). The direct effect of MA on reading comprehension was also significant, β = .108 [.009, .199]. So were the indirect effects of MA, β = .175 [.128, .229] via word reading and β = .199 [.149, .255] via vocabulary knowledge. The overall pattern found in the whole sample, that is, the direct and indirect effects of MA on reading comprehension were significant, held for both language subgroups.

Table 2

Estimates of Direct and Indirect Effects Based on the Whole Sample (k = 107)

Path/effect	Coefficient estimates	95% CI
Direct effects		
NVR → MA	.301	[.242, .361]
NVR → WR	.190	[.109, .265]
NVR → VK	.171	[.118, .222]
NVR → RC	.090	[.029, .149]
MA → WR	.512	[.469, .556]
MA → VK	.511	[.478, .544]
MA → RC	.146	[.082, .208]
WR → RC	.274	[.209, .336]
VK → RC	.371	[.320, .422]
Indirect effects		
MA → WR → RC	.140	[.105, .177]
MA → VK → RC	.190	[.160, .221]

Note. NVR = nonverbal reasoning; MA = morphological awareness; WR = word reading; VK = vocabulary knowledge; RC = reading comprehension.

To compare the magnitude of the effects between the two subgroups, a set of multi-group path analyses was conducted with equality constraints placed on different paths between the four literacy variables. They included the three direct effects of MA (i.e., MA → Word Reading; MA → Vocabulary Knowledge; and MA → Reading Comprehension); the two direct effects of word reading and vocabulary knowledge on reading comprehension; and the two indirect effects of MA on reading comprehension (i.e., MA → Word Reading → Reading Comprehension; MA → Vocabulary Knowledge → Reading Comprehension). None of the three direct paths of MA to reading outcomes (albeit all significant; see Table 3) differed significantly between monolinguals and bilinguals in terms of the magnitude of the path coefficients. A significant difference surfaced in the path from word reading to reading comprehension, $\Delta\chi^2(1) = 7.666$, $p = .006$, stronger in monolinguals (β = .332) than in bilinguals (β = .159). The indirect effect of MA on reading comprehension via word reading was also stronger in monolinguals (β = .175) than in bilinguals (β = .077), $\Delta\chi^2(1) = 8.370$, $p = .015$. The indirect effect of MA via vocabulary knowledge did not differ significantly between the two subgroups. Table S5c in the online supplemental materials shows the full results of the multi-group path analyses.

Subgroup Comparisons Based on Age/Grade

Following the same procedure, we conducted TSSEM for each age/grade subgroup, including lower elementary ($k = 13$; $N = 1{,}711$), upper elementary ($k = 47$; $N = 6{,}952$), and middle/high school ($k = 46$; $N = 13{,}083$) and then compared the strength of the path coefficients between the four literacy variables through multi-group path analysis. Table S6a–c in the online supplemental

Table 3
Estimates of Direct and Indirect Effects Based on Moderator Analysis for Language Status

Path/effect	Bilingual ($k = 46$)	Monolingual ($k = 60$)
Direct effects		
NVR → MA	.158 [.066, .251]	.408 [.357, .458]
NVR → WR	.328 [.183, .468]	.124 [.033, .212]
NVR → VK	.219 [.156, .280]	.130 [.045, .211]
NVR → RC	.091 [–.030, .208]	.099 [.018, .180]
MA → WR	.486 [.420, .546]	.527 [.463, .590]
MA → VK	.494 [.450, .537]	.534 [.480, .588]
MA → RC	.201 [.120, .285]	.108 [.009, .199]
WR → RC	.159 [.152, .251]	.332 [.251, .414]
VK → RC	.381 [.315, .445]	.372 [.289, .458]
Indirect effects		
MA → WR → RC	.077 [.027, .125]	.175 [.128, .229]
MA → VK → RC	.188 [.153, .226]	.199 [.149, .255]

Note. NVR = nonverbal reasoning; MA = morphological awareness; WR = word reading; VK = vocabulary knowledge; RC = reading comprehension.

materials shows the results of the Stage 1 analysis for the three subgroups, respectively. The path model, based on the Stage 2 analysis, showed good model fits for all three subgroups: $\chi^2(1) = 12.726$, $p < .001$; CFI = 0.991, RMSEA = 0.083, 95% CI [.047, .126], SRMR = 0.039; $\chi^2(1) = 23.016$, $p < .001$; CFI = 0.993, RMSEA = 0.056, [.038, .077], SRMR = 0.036; and $\chi^2(1) = 10.558$, $p = .001$; CFI = 0.996, RMSEA = 0.027, [.014, .043], SRMR = 0.045, respectively.

As shown in Table 4, among the four literacy variables, the direct and indirect effects were all significant with one notable exception, that is, the direct effect of MA on reading comprehension in the lower elementary subgroup. In the lower elementary subgroup, MA significantly predicted word reading (β = .515; 95% CI [.432, .593]) and vocabulary knowledge (β = .500; [.423, .578]). Its direct effect on reading comprehension, over and above word reading and vocabulary knowledge, however, was not significant, β = .127 [−.002, .244]. Word reading (β = .541; [.421, .662]) and vocabulary knowledge (β = .178; [.087, .272]) significantly predicted reading comprehension. The indirect effects of MA on reading comprehension were also significant: β = .279 [.206, .366] via word reading and β = .089 [.042, .146] via vocabulary knowledge. For the upper elementary subgroup, MA also significantly predicted word reading (β = .565; [.487, .643]) and vocabulary knowledge (β = .517; [.456, .577]). MA (β = .123; [.024, .212]), word reading (β = .269; [.192, .346]), and vocabulary knowledge (β = .372; [.296, .449]) were each a significant and unique predictor of reading comprehension. The indirect effects of MA on reading comprehension were also significant: β = .152 [.104, .208] via word reading and β = .193 [.146, .244] via vocabulary knowledge. Finally, for the middle/high school subgroup, MA was also a significant predictor of word reading (β = .480; [.415, .541]) and vocabulary knowledge (β = .502; [.451, .551]). MA (β = .205; [.114, .293]), word reading (β = .148; [.067, .224]), and vocabulary knowledge (β = .434; [.355, .514]) were also each a significant and unique predictor of reading comprehension. The indirect effects of MA on reading comprehension were also significant: β = .071 [.032, .110] via word reading and β = .218 [.174, .268] via vocabulary knowledge.

Subgroup comparison results based on multi-group path analysis are summarized in Table 4 with the full results presented in Table S6d in the online supplemental materials. None of the direct paths of MA to reading outcomes significantly differed in magnitude between any two subgroups. The effect of word reading on reading comprehension was significantly stronger in the lower elementary subgroup (β = .541) than in the upper elementary group (β = .269). It was also stronger in these two subgroups than in the middle/high school subgroup (β = .148). A converse pattern was found for the effect of vocabulary knowledge on reading comprehension. This effect was the smallest in the lower elementary subgroup (β = .178) but did not differ between the upper elementary (β = .372) and the middle/high school subgroups (β = .434). The same pattern of the relative strength of path coefficients was found for the indirect effects of MA on reading comprehension. For the MA → Word Reading → Reading Comprehension route, the lower elementary subgroup (β = .279) showed the strongest effect, followed by the upper elementary subgroup (β = .152) and the middle/high school subgroup (β = .071). In contrast, for the MA → Vocabulary Knowledge → Reading Comprehension route, the upper elementary (β = .218) and the middle/high school subgroups

Table 4
Estimates of Direct and Indirect Effects Based on Moderator Analysis for Age/Grade

Path/effect	Lower elementary (LE; $k = 13$)	Upper elementary (UE; $k = 47$)	Middle/high (MH; $k = 46$)	Summary of subgroup comparisons
Direct effects				
NVR → MA	.373 [.279, .467]	.416 [.355, .478]	.161 [.066, .256]	—
NVR → WR	.196 [.099, .290]	.123 [.006, .233]	.226 [.079, .363]	—
NVR → VK	.092 [–.024, .201]	.188 [.084, .287]	.205 [.130, .274]	—
NVR → RC	.124 [.046, .203]	.084 [–.011, .177]	.056 [–.028, .136]	—
MA → WR	.515 [.432, .593]	.565 [.487, .643]	.480 [.415, .541]	LE = UE = MH
MA → VK	.500 [.423, .578]	.517 [.456, .577]	.502 [.451, .551]	LE = UE = MH
MA → RC	.127 [–.002, .244]	.123 [.024, .212]	.205 [.114, .293]	LE = UE = MH
WR → RC	.541 [.421, .662]	.269 [.192, .346]	.148 [.067, .224]	LE > UE > MH
VK → RC	.178 [.087, .272]	.372 [.296, .449]	.434 [.355, .514]	UE = MH > LE
Indirect effects				
MA → WR → RC	.279 [.206, .366]	.152 [.104, .208]	.071 [.032, .110]	LE > UE > MH
MA → VK → RC	.089 [.042, .146]	.193 [.146, .244]	.218 [.174, .268]	UE = MH > LE

Note. NVR = nonverbal reasoning; MA = morphological awareness; WR = word reading; VK = vocabulary knowledge; RC = reading comprehension; LE = lower elementary; UE = upper elementary; MH = middle/high.

(β = .193) did not differ significantly; both subgroups, however, showed a stronger effect than the lower elementary subgroup (β = .089).

Subgroup Comparisons Based on MA Task Modality

TSSEM was conducted separately for the two subgroups of primary studies where MA tasks involved spoken language (the spoken-task subgroup; $k = 56$; $N = 7{,}187$) and where the tasks were written-based (the written-task subgroup; $k = 51$; $N = 14{,}631$). It was followed by comparisons of the strength of the path coefficients between the two subgroups through multi-group path analysis. Table S7a and b in the online supplemental materials show the Stage 1 results for the two subgroups. The model, based on the Stage 2 analysis, showed good model fits for both subgroups: $\chi^2(1) = 33.620$, $p < .001$; CFI = 0.993, RMSEA = 0.067 (95% CI [.049, .088]), SRMR = 0.032 for the spoken-task subgroup; $\chi^2(1) = 9.062$, $p = .003$; CFI = 0.996, RMSEA = 0.024 [.011, .039], SRMR = 0.062 for the written-task subgroup.

The direct and indirect effects were all significant for both subgroups (see Table 5). In the spoken-task subgroup, MA significantly predicted word reading (β = .540; 95% CI [.486, .592]) and vocabulary knowledge (β = .523; [.477, .567]). Over and above word reading and vocabulary knowledge, MA also significantly predicted reading comprehension, β = .138 [.065, .206]. The indirect effects of MA on reading comprehension were also significant: β = .162 [.120, .207] via word reading and β = .176 [.141, .213] via vocabulary knowledge. The same pattern was found for the written-task subgroup. MA significantly predicted word reading (β = .475; [.390, .552]) and vocabulary knowledge (β = .485; [.428, .540]). Its direct effect on reading comprehension was significant as well, β = .180 [.075, .283]. So were its indirect effects on reading comprehension: β = .097 [.037, .158] via word reading and β = .206 [.157, .263] via vocabulary knowledge.

Multi-group path analyses found no significant difference between the two subgroups in the magnitude of the direct paths of MA to word reading, vocabulary knowledge, and reading comprehension as well as that of the two indirect paths of MA to reading comprehension. Detailed results of the analyses are presented in Table S7c in the online supplemental materials. These findings suggest that whether spoken language was involved in MA task administration did not affect the overall strength of the associations between MA and reading outcomes.

Table 5
Estimates of Direct and Indirect Effects for Moderator Analysis on MA Task Modality

Path/effect	Spoken ($k = 56$)	Written ($k = 51$)
Direct effects		
NVR → MA	.406 [.354, .457]	.164 [.068, .259]
NVR → WR	.130 [.052, .205]	.340 [.168, .505]
NVR → VK	.152 [.079, .223]	.208 [.135, .278]
NVR → RC	.112 [.048, .176]	.037 [.024, .153]
MA → WR	.540 [.486, .592]	.475 [.390, .552]
MA → VK	.523 [.477, .567]	.485 [.428, .540]
MA → RC	.138 [.065, .206]	.180 [.075, .283]
WR → RC	.299 [.228, .371]	.204 [.079, .327]
VK → RC	.336 [.278, .394]	.426 [.333, .519]
Indirect effects		
MA → WR → RC	.162 [.120, .207]	.097 [.037, .158]
MA → VK → RC	.176 [.141, .213]	.206 [.157, .263]
MA → WR + VK → RC	.337 [.278, .401]	.303 [.220, .391]

Note. NVR = nonverbal reasoning; MA = morphological awareness; WR = word reading; VK = vocabulary knowledge; RC = reading comprehension.

Discussion

This MASEM study tested a path model of the direct and indirect effects of MA on reading comprehension with concurrent considerations of word reading and vocabulary knowledge. It also conducted subgroup comparisons based on three moderators, that is, readers' language status, age/grade, and MA task modality.

Direct and Indirect Effects of MA and Subgroup Comparisons

To answer the first set of research questions, the path analysis based on the pooled correlation matrix showed that in the whole sample, MA significantly predicted and had a large effect on word reading (β = .512) and vocabulary knowledge (β = .511; Acock, 2014: β smaller than .20 weak; .20–.50 moderate; larger than .50 strong). Over and above word reading and vocabulary knowledge, the direct effect of MA on reading comprehension was also significant, albeit small (β = .146). Its indirect effect was also significant, suggesting the effects of MA on reading comprehension were partially mediated by word reading and vocabulary knowledge. These findings provide robust evidence on the importance of MA in reading acquisition, including reading comprehension. They lend support to the theoretical accounts synthesized earlier in this article on the distinct routes (code/form, meaning, and syntactic; direct and indirect) through which MA contributes to reading comprehension (see also Nagy et al., 2014; Levesque et al., 2021). The following discussion focuses on the findings of subgroup comparisons, which answered the second set of research questions on moderator analysis.

Bilingual Versus Monolingual Readers

The effects of MA on all three literacy measures, including the two routes of indirect effects on reading comprehension, were significant for both monolinguals and bilinguals. The direct effects of MA on word reading, vocabulary knowledge, and reading comprehension did not differ significantly between the two subgroups. This further supports the robust importance of morphology in English reading acquisition, whether English is the native or second language. It suggests that the mechanisms discussed earlier for MA in reading comprehension reflect the general principles of English reading acquisition as mandated by the morphological properties of words and their representations in print (Carlisle, 2003; Levesque et al., 2021; Nagy et al., 2014).

Based on the standardized coefficient estimates, monolinguals showed balanced reliance on word reading and vocabulary knowledge (both moderate in size; Acock, 2014) in reading comprehension, whereas for bilinguals, the contribution of vocabulary knowledge (moderate in size) was stronger than that of word reading (weak in size). The greater reliance of bilinguals on vocabulary knowledge in reading comprehension corroborates Jeon and Yamashita's (2014) univariate meta-analytic finding that vocabulary knowledge had a much higher correlation with reading comprehension than did decoding in L2 readers. It is also in line with previous findings and discussions on the particular importance of vocabulary or meaning-based skills for reading or academic achievement in bilinguals/English Learners (ELs) (August & Shanahan, 2006; Carlo et al., 2004; Proctor et al., 2005). In the United States, ELs or language-minority students tend to come from low-SES families where early English exposure is usually very limited for developing oral language proficiency, notably oral vocabulary, which has a substantial impact on their reading development (Hoff, 2013; Kieffer, 2008; Luo et al., 2021).

It is interesting that the indirect effect of MA on reading comprehension via word reading was significantly smaller in bilinguals than in monolinguals. This could be a result of the significantly smaller effect of word reading on reading comprehension in bilinguals. This finding suggests that for bilingual readers, the code-based route, that is, MA → Word Reading → Reading comprehension, is perhaps of less importance. Accordingly, it also seems to imply that meaning-based morphological skills, that is, a capacity for morphological analysis and meaning construction, may be more important and deserve special attention in morphological instruction for bilingual readers (Goodwin et al., 2012; Kieffer & Lesaux, 2007).

Lower Elementary, Upper Elementary, and Middle/High School

MA significantly predicted word reading and vocabulary knowledge, and the strength of these effects did not differ significantly in the three age/grade subgroups. The effects of MA on reading comprehension, however, showed notable subgroup differences. While the direct effect of MA on reading comprehension, over and above word reading and vocabulary knowledge, was significant for the upper elementary and middle/high school subgroups, it was not the case for the lower elementary or the youngest subgroup. Early in this article, we discussed two distinct mechanisms for the MA → Reading Comprehension route, that is, morphological analysis to resolve any vocabulary gaps during reading and syntactic parsing (Paths 3a and 3b, respectively, in Figure 1; Nagy et al., 2014). Considering that all three subgroups demonstrated a similar large effect of MA on vocabulary knowledge, which perhaps implied a similar capacity for morphological problem-solving, this difference on the MA → Reading Comprehension route may be attributed to the youngest subgroup's limited awareness of the syntactic functions of English suffixation. Tyler and Nagy (1989) found that it was particularly challenging for young readers of English to understand the principles that govern how suffixes combine with stems (i.e., distributional properties of derivation). The present meta-analytic finding on MA seems to support the importance found of syntactic awareness for reading comprehension in monolingual as well as bilingual readers of English (e.g., Deacon & Kieffer, 2018; Jeon & Yamashita, 2014).

There were notable subgroup differences in the relative magnitude of the indirect effects of MA on reading comprehension via word reading and vocabulary knowledge, despite both being significant in all subgroups. The indirect effect via word reading decreased from younger to older subgroups. It was moderate in size for the lower elementary subgroup but small for the other two groups. In contrast, the indirect effect via vocabulary knowledge became stronger, being moderate in the upper elementary and the middle/high school subgroups and small in the youngest subgroup. This could be a result of the similar pattern found in the effect of word reading and vocabulary knowledge on reading comprehension, respectively; that is, the role of word reading decreased, whereas that of vocabulary knowledge increased over time. This meta-analytic finding supports observations that as children progress in school, particularly as they transition from the "learning to read" stage to the "reading to learn" stage, vocabulary knowledge becomes increasingly important, whereas the importance of decoding gradually weakens (Chall & Jacobs, 2003; Paris, 2005). It also corroborates previous studies that explored developmental variations in the relative effects of decoding and language comprehension (vocabulary and listening comprehension) on reading comprehension (e.g., Ouellette & Beers, 2010; Tilstra et al., 2009). Previous univariate meta-analyses also found that, while the correlation between decoding and reading comprehension decreased with increasing age (García & Cain, 2014), that between vocabulary knowledge and reading comprehension became stronger (Jeon & Yamashita, 2014).

Based on these findings, compared to older readers, younger readers would seem to benefit more from morphological instruction that promotes the use of morphemes (a larger-size unit) and chunking strategies, in addition to phonemic decoding, for word reading, especially morphological decoding fluency. An emphasis may be particularly needed, at upper elementary and above, on nurturing children's capacity to learn new words and expand vocabulary through morphological problem-solving. This, of course, by no means suggests that meaning-oriented morphological instruction should be ignored for young, beginning readers. After all, for the lower elementary subgroup, MA also significantly predicted vocabulary; and the MA → Vocabulary Knowledge → Reading Comprehension route was also significant. Morphological instruction for any age group perhaps needs to have a built-in meaning focus, underscoring how morphemes combine to generate new meaning for children to benefit reading comprehension in the long run (Carlisle, 2007; Goodwin et al., 2012; Kieffer & Lesaux, 2007).

MA Task Modality

The present meta-analysis did not find any significant moderation effect of MA task modality (see also Ruan et al., 2018). We speculate that although spoken MA tasks hypothetically may reduce the correlation between MA and word reading, the involvement of phonological skills–which are fundamental for decoding–in understanding spoken language means that the correlation could be conversely affected. This conjecture may hold in particular considering that spoken MA tasks necessitate the processing of multisyllabic/multimorphemic words, which tend to be phonologically more complex, and that these tasks are more likely administered to early readers for whom PA is very important, or even more important than MA, in word reading (see Ruan et al., 2018). As shown in Table 5, the correlations of MA with both word reading and vocabulary knowledge (the latter was commonly measured as oral vocabulary using Peabody Picture Vocabulary Test; see Table S1 in the online supplemental materials) appeared stronger when MA tasks involved oral language, which seems to provide further support for the phonological account.

Limitations and Future Research

The present meta-analysis has a few limitations due to its defined goal and focus. These limitations perhaps also largely reflect some issues in the primary research literature that warrant attention in the future. First, we only focused on three moderators. It is generally advised that MASEM studies consider a small set of moderators (Cheung & Chan, 2005; Jak, 2015; Jak & Cheung, 2018). This seems to have been the case for existing MASEM studies on reading (e.g., H. Lee et al., 2022; Hjetland et al., 2020; Peng et al., 2021). Depending on their specific goals, future MASEM studies might test other moderators, such as word reading tasks (e.g., accuracy vs. fluency; decoding "general" words vs. morphologically complex words), vocabulary knowledge (e.g., written vs. oral), and reading comprehension (e.g., types of comprehension; text types; comprehension measures). Likewise, MA tasks might be coded further for other facets (e.g., structural focus or receptive vs. productive). The possibility of these potential moderator analyses arguably depends on a sufficient number of primary studies with study features codable for running random-effects models. At present, it is impossible to test many of these additional moderators for the path model of the present study because they are either uncodable of the included studies or the subgroup size for some is extremely small.[2] The former reason also explained why SES was neither included as a covariate in the path model nor as a moderator of any path coefficients. Likewise, the latter was the same reason why further subgrouping was impossible for enabling the testing of any confounding or interaction between the three moderators and path coefficients in this study. All the moderations were conducted without controlling for the possible confounding effects among other moderators, and therefore, the moderation findings should be interpreted with some caution.

Second, future primary research is much needed to explore the meaning- and syntax-based routes of MA in reading comprehension. Although the morphological analysis or problem-solving mechanism has been much discussed (Goodwin et al., 2012; Nagy et al., 2014), studies on MA and reading comprehension rarely include a measure for this skill and test how it connects MA, vocabulary knowledge, and reading comprehension (see Deacon et al., 2017; Zhang & Koda, 2012; J. Zhang et al., 2020 for notable exceptions). For the model tested for this MASEM study, the number of effect sizes for paths potentially involving morphological analysis would be too small for some subgroups to enable any moderator analysis. This was the same reason why syntactic awareness was not considered for the path model in the present study.

Finally, the correlation matrices meta-analyzed were largely based on concurrent relations. The moderator analysis on age/grade did not directly inform developmental change. In the primary literature, autoregressive effects were sometimes considered for testing a more robust effect of MA on reading comprehension longitudinally (e.g., Deacon et al., 2014; Zhang, 2017). Developmental interdependence between MA and reading was also occasionally explored (e.g., Kruk & Bergman, 2013). Longitudinal research of these kinds, however, is very limited, which prevents any MASEM study at present from focusing exclusively on longitudinal correlations.[3] For the same reason, it is impossible to test at present how the strength of the association between MA and reading comprehension may vary as a function of time lag (see Lin & Powell, 2022 for an exploration of this issue in mathematical learning; see also Jak & Cheung, 2020).

Conclusion

This paper reported the first MASEM study on MA and reading comprehension in school-aged readers of English. MA significantly predicted word reading and vocabulary knowledge, controlling for nonverbal reasoning skills. More importantly, the direct and indirect effects of MA on reading comprehension were significant for the full sample as well as all subgroups except the lower elementary subgroup. Different from monolinguals, vocabulary knowledge played a much more salient role in reading comprehension than did word reading in bilinguals. The MA → Word Reading → Reading Comprehension route became increasingly weaker, whereas the MA → Vocabulary Knowledge → Reading Comprehension route became stronger as children moved up grades in schools. Task modality did not affect the relations of MA with reading outcomes, which perhaps serves as a call for re-considering the goal of using spoken language to avoid or reduce decoding involvement in MA task administration.

These meta-analytic findings provided robust evidence on the importance of morphology in English reading acquisition, in particular, *how* MA contributes to reading comprehension. They also enhanced our understanding of how the strength of association between MA and reading comprehension may differ between native-speaking and bilingual/L2 readers and how the mechanisms for MA in reading comprehension may also change developmentally. These issues often were not directly investigated in individual primary studies and explored in previous univariate meta-analyses on morphology and reading (Ke et al., 2021; J. W. Lee et al.,

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[2] A case in point is perhaps the structural focus of MA measures. We coded this feature but had to exclude it as a moderator because the included studies focused predominantly on derivation (see Table S2 in the online supplemental materials). In fact, among the 107 effect sizes, for the ten correlations, *k* ranged from 0 to 1 and from 0 to 4, respectively, for those where MA measures had a sole focus on inflection and compounding. This prevented running any moderator analysis on morphological structure for the path model tested in this MASEM study.

For the same reason about the small subgroup size, we did not aim to code MA-related correlations separately for different measures and incorporate MA as a latent variable in the model shown in Figure 1. A large majority of the included studies did not report separate correlations for MA when more than one measure was included (e.g., Ku & Anderson, 2003; Nagy et al., 2006). For those where multiple correlations were reported that involved two or more MA measures, task dimensions or facets often varied significantly, such as derivation vs. compounding (e.g., Wang et al., 2006), real vs. pseudo base for the affix choice task (e.g., Zhang et al., 2016), and the construction vs. decomposition aspects of Carlisle's (2000) morphological structure test (e.g., Kruk & Bergman, 2013). These prevented coding correlations to represent a latent MA that would also allow for moderator analysis on language status and age/grade. Consequently, the model tested for this MASEM study was a path model without a measurement component. A reviewer was concerned that without MA being measured on a common scale, multi-group analysis not considering scale invariance would not "disentangle whether results are a consequence of scale non-invariance or group differences." We admit the legitimacy of this concern and wish to point this out as a limitation of this study. We, however, also wish to add that while this limitation was a result of the reality we discussed in the primary research literature, it perhaps pertains to current correlation-based meta-analyses in general. It is hoped that the moderator analysis conducted on MA tasks addressed this concern to some extent. In this study, none of the direct and indirect effects of MA on reading outcomes were found to differ significantly between spoken and written MA measures.

[3] Among the 107 effect sizes that met the inclusion and exclusion criteria for this meta-analysis, only 16 (about 15%) were longitudinal in nature. Among these 16 effect sizes, only 12 reported longitudinal correlations that involved the relations of earlier MA with later reading comprehension, and further, only six reported reciprocal longitudinal correlations between MA and reading comprehension that would enable any potential cross-lagged path analysis between these two variables.

2022; Ruan et al., 2018). The present MASEM study, which combined meta-analysis and SEM, provided a unique opportunity to address these issues and filled a research gap.

Morphological instruction, depending on the approach, may "support some of the paths more than others" (Nagy et al., 2014, p. 6) and may accordingly generate differential effects on different reading outcomes (e.g., word reading vs. reading comprehension) and in different readers (e.g., native-speaking vs. ELs; younger vs. older; Bowers et al., 2010; Goodwin & Ahn, 2013). In this respect, this study's comparisons of the relative magnitude of the different paths for different reading skills and in different reader groups seem to shed light on targeted morphological instruction. For example, while both monolingual and bilingual readers may benefit from meaning-focused morphological instruction, such as morphological analysis, this type of instruction may be particularly important for reading comprehension in bilingual readers (e.g., Goodwin & Ahn, 2013). In the United States, where language-minority students are more likely to study in urban schools and are at a greater risk of poor comprehension and low achievement, meaning-focused morphological instruction seems essential for promoting their vocabulary development (Carlo et al., 2004; Kieffer & Lesaux, 2007). In a foreign language context, this type of instruction may be even more urgent, because children's social exposure to English is typically very limited and language and reading development depend heavily on classroom instruction. For younger readers, as the results of the moderator analysis on age/grade suggested, it seems desirable that English morphological instruction integrate skills for decoding, morphological analysis, vocabulary, and syntactic aspects of affixation, that is, balanced attention to code/form, meaning, and syntax-based routes, for their reading comprehension to be benefited in the long run. For older readers, the instruction may be more saliently focused on morphological analysis and vocabulary expansion. Taken together, the present meta-analytic findings suggest that morphological instruction may need to be targeted or differentiated and responsive to children's language status and stage of schooling. Intervention studies seem particularly needed in the future that incorporate goals on the capacity of using morphology for building meaning for bilingual readers at upper elementary school and above.

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