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Morphological Awareness and DHH Students' Reading-Related Abilities: A Meta-Analysis of Correlations

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Abstract

This article presents the first meta-analysis on correlations of morphological awareness (MA) with reading-related abilities in deaf and hard-of-hearing (DHH) students ($k = 14$, $N = 556$). The results showed high mean correlations of MA with all three reading-related abilities: $rs = 0.610$, 0.712, and 0.669 (all $ps < 0.001$), respectively, for word reading, vocabulary knowledge, and reading comprehension. A set of moderator analysis was conducted of language, DHH students' age/reading stage and degree of hearing loss, and task type. The correlation of MA with word reading was significantly stronger in alphabetic than in non-alphabetic languages, and for fluency than accuracy; for vocabulary knowledge, the correlation was significantly stronger for production MA tasks than for judgment tasks; for reading comprehension, derivational MA tasks showed a stronger correlation than those having a mixed focus on inflection and derivation. While no other moderator effects were significant, the correlations for subsets of effect sizes were largely high for a moderator. These findings reaffirmed the importance of morphology in DHH students' reading development. The present synthesis, while evidencing major development of research on the metalinguistic underpinnings of reading in DHH students, also showed that the literature on MA is still very limited.

Reading acquisition depends heavily on the ability to map spoken language elements onto their written representations (Perfetti, 2003; Perfetti & Sandak, 2000). The Qualitative Similarity Hypothesis (QSH) (Paul et al., 2013; Paul & Lee, 2010) contends that deaf and hard-of-hearing (DHH) children, like any other groups of typical literacy learners, go through a similar process of reading acquisition where a set of fundamental skills is necessitated (i.e., a similar *manner* of development or a *qualitative* similarity). Many studies have examined and debated, phonology and its related skills (e.g., phonological awareness [PA], cued speech, visual phonics, and speechreading) in DHH students' reading development (Alasim & Alqraini, 2020; Luft, 2018; Mayberry et al., 2011; Miller & Clark, 2011). Morphology, despite being the focus of a plethora of studies over the past decades (Levesque et al., 2021; Nagy et al., 2014), however, has received rather limited attention in the literature on reading in DHH students. Morphological awareness (MA) is a type of metalinguistic awareness often defined as the ability to manipulate morphemes (the smallest unit of meaning) and reflect on morphological structures of words (Carlisle, 2003; Kuo & Anderson, 2006). MA has been identified as a significant correlate and predictor of various reading-related abilities in hearing students of diverse backgrounds (Lee et al., 2023; Ruan et al., 2018). In the literature on DHH students, other than a few narrative reviews (e.g., Cannon & Trussell, 2021; Gaustad, 2000; Nielsen et al., 2011), there has been little effort to systematically review studies on MA and reading (see, however, Trussell & Easterbrooks, 2017), not to mention any meta-analysis on their correlations.

This article thus sets out to fill the gap and aims to achieve two main goals. First, it provides a scoping review of existing correlation-based studies, describing major study features. Second, it presents the first meta-analysis on correlations of MA with word reading, vocabulary knowledge, and reading comprehension. Considering that the sample size in primary studies on DHH students is typically small, pooling correlations across multiple studies to generate a weighted mean correlation through meta-analysis seems particularly important for producing more reliable evidence to guide morphological and reading instruction for DHH students.

Morphological Awareness and Reading Development

MA is a multidimensional and multifaceted construct that entails different types and levels of insights depending on morphological structure and the ways in which morphological information is encoded in print (Kuo & Anderson, 2006). In English, for example, studies on MA and reading have focused predominantly on

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derivation, although MA aspects on inflection and compounding have also been studied. Inflection involves adding suffixes, such as the third-person singular -*s* and the past tense -*ed*, to a base word. This morphological process is closely related to morphosyntactic functions of nouns and verbs but does not alter their meanings and yield new words. In English, there is only a very limited set of inflectional suffixes; and inflection is overall a regular process with limited morphophonemic or morphographic changes (Bauer & Nation, 1993). Research on monolingual children shows that awareness of inflection tends to mature at an early stage of learning to read, although error-free spelling of inflected words may not happen until late elementary school (Carlisle, 2003; Kuo & Anderson, 2006). In comparison to inflection, derivation is a far more complex process and has been shown to pose many challenges for English reading acquisition. Not only is there a much larger set of derivational affixes of different origins (e.g., Germanic and Latinate) but derivational suffixation often results in orthographic and/or phonological changes in a base word (Carlisle, 2003). Importantly, derivation is also a highly productive process for creating new words in English. Adding an affix not only modifies the meaning of a base word but often also changes the grammatical status of the word as well. These characteristics of derivation mean that the development of derivational MA, in comparison to that of inflectional awareness, is a much slower process. In English-speaking children, while structural aspects of derivational MA, such as the understanding that *teacher* and *teach* are related whereas *corner* and *corn* are not, are acquired early in elementary school, more refined aspects, such as suffixation modifying the part-of-speech of a word and the distributional properties of derivation (e.g., –*less* requires to be added to a noun to form an adjective), take a much longer time to develop (Tyler & Nagy, 1989).

MA entails an analytic approach to morphologically complex words. A notable contribution of MA to reading development lies in its mechanism for facilitating word learning and vocabulary development through morphological analysis. Multimorphemic words are prevalent in print (Nagy & Anderson, 1984). At any stage of schooling or reading development, students constantly encounter unknown multimorphemic words and learn those words based on “morphological problem-solving” (Anglin et al., 1993), that is, unlocking the meaning of a word based on its constituent morphemes. Many studies have found MA as a significant predictor of vocabulary knowledge and its growth in diverse groups of readers, including monolingual children of Chinese, English and Korean (e.g., McBride-Chang et al., 2008) and second language (L2) readers (e.g., Kieffer & Lesaux, 2012a; Zhang et al., 2016).

In English, while in lower elementary grades, PA (especially phonemic awareness) plays a more important role than MA, the latter gradually becomes a stronger predictor of word reading, especially decoding fluency, in upper elementary school and beyond. This pattern is perhaps developmentally congruent with children’s greater exposure to morphologically complex words in school English and the greater importance of word reading fluency rather than basic accuracy for text reading and comprehension (García & Cain, 2014). Efficient word recognition requires high-quality representations of word identity features and mechanisms that bind these features (Perfetti, 2007). Morphology is underscored as a “binding agent” that can strengthen “the links between the orthographic, phonological, and meaning representation of words” (Nagy et al., 2014, p. 10). High-quality morphemic representations suggest other well-developed and overlapping aspects of word identity. The redundancy in representations facilitates word reading, especially fluency (Nagy et al., 2014). Developmentally, the importance of MA for word reading, and its relative importance with that of PA, is also in line with stage models of reading acquisition where English-speaking children at a relative late stage (e.g., the consolidated alphabetic phase in Ehri, 2005) employ chunking (e.g., syllables and morphemes) to read words. Numerous studies have found MA as a significant predictor, over and above phonological skills, of both word reading accuracy and fluency across languages and reader groups (see the meta-analytic findings reported in Ke et al., 2021; Lee et al., 2023; Ruan et al., 2018).

MA has also been found as a significant correlate/predictor of reading comprehension (Jeon & Yamashita, 2014; Ruan et al., 2018). Compared to the mechanisms discussed above for vocabulary and word reading, how MA contributes to reading comprehension has remained less clear. Some (e.g., Levesque et al., 2021; Nagy et al., 2014) contend that the contribution may be largely indirect, as a result of the importance of MA for vocabulary and word reading on the one hand and that of vocabulary and word reading (especially fluency) for reading comprehension on the other (Kieffer & Lesaux, 2012b; Zhang, 2017). Nagy (2007) further contends that MA is important for instantaneous resolution of vocabulary gaps during reading. When readers encounter an unknown word in a text, they may utilize morphological insights to analyze the word and infer its meaning, which helps resolve the lexical gap that may hinder comprehension of the text. In English, the grammatical functions of derivational suffixation may also facilitate sentence parsing and consequently reading comprehension. This may be particularly the case for reading academic texts where grammatical metaphors such as nominalization are prevalent and commonly build on derivation (Nagy et al., 2014; Nagy & Townsend, 2012).

Morphology, Reading and DHH Readers

The QSH (Paul et al., 2013; Paul & Lee, 2010) contends that reading acquisition in DHH children, like in any other groups of typical literacy learners, undergo similar processes with a similar set of underpinning skills necessitated (see also Perfetti & Sandak, 2000). Gaustad and colleagues (Gaustad, 2000; Gaustad & Paul, 1998) proposed a morphographic model of English word identification that is based on DHH students’ well-developed visual skills and general segmental awareness (morphological and orthographic). Morphographic analysis of words (or “meaning-based decoding strategies”) is argued as an important “supplement” or “alternative” to graphophonemic skills or “sound-based word identification skills” for DHH students (Gaustad & Paul, 1998, p. 202). It is highlighted that “morphographic correspondence in English is much more reliable (i.e., consistent and predictable with fewer exceptions) than is graphophonemic correspondence (Gaustad & Paul, 1998, p. 203); and that “morphographic analysis can be a more efficient (faster and more reliable) route to word identification for multimorpheme words than phonological recoding is” (Gaustad, 2000, p. 66). The fact that school texts are replete with morphologically complex words suggests that the mandate of MA for word learning and reading development, as discussed in the previous section, should hold for DHH students as well. Many scholars, such as Gaustad (2000), Nielsen et al. (2011), Trussell and colleagues (e.g., Trussell, 2020; Trussell & Easterbrooks, 2015), to name just a few, all accordingly underscore the importance of morphological instruction for promoting DHH students’ vocabulary knowledge, word reading (especially fluency), reading comprehension, and writing. Gaustad (2000), for example, proposed a tiered approach with three levels of morphographs (Level 1: inflectional affixes; Levels 2 & 3: derivational affixes; and Level 3: roots) to guide English morphographic analysis and instruction for DHH students. Nielsen et al. (2011) discussed how Signing Exact English or the "through the air" method to visually represent English roots and affixes may benefit DHH students' morphological experience and MA development. Note, however, that the actual effect of this approach, which is often known as SEE-II, remains unclear (see, for example, Greene-Wood', 2020 commentary on Nielsen et al., 2016). The approach itself is often also contested with increasing concerns over or an objection to the use of signing systems, as opposed to a natural sign language (e.g., American Sign Language or British Sign Language), for educating DHH students (Scott & Henner, 2021).

Despite the importance underscored of different tiers of affixes/morphemes, most studies on DHH students so far seemed to have largely focused on inflection or morphosyntactic aspects of language (see Cannon & Trussell, 2021). This seems to show a notable distinction from the literature on hearing readers where, as discussed earlier, a much stronger focus has been on derivation. The distinct focus on DHH students may be attributed to the fact that inflectional suffixes, such as the third-person singular -*s* and the past tense -*ed*, which have important syntactic functions and thus strong implications for productive language use (especially writing in school), are phonologically low in perceptual salience, and thus may not be effectively perceived and acquired by DHH children through early spoken language experience (Cannon & Trussell, 2021; Guo et al., 2013). Although the fitting of hearing devices such as hearing aid (HA) or cochlear implant (CI) can ameliorate challenges in early spoken language development, the actual auditory experience of individual children may vary significantly, depending on the age of hearing loss diagnosis, degree of hearing loss, time of HA and CI fitting, and aided hearing level, not to mention the heterogeneity in mode of communication and educational experience later in school. Many studies aimed to examine DHH children's English morphosyntactic development, based on varied types of evidence, such as direct measures of (inflectional) morphological knowledge using experimental tasks (e.g., Davies et al., 2020; Gaustad et al., 2002), error analysis of misconstructed inflected forms in spoken language production (e.g., C. Goodwin & Lillo-Martin, 2019; Guo et al., 2013) and writing/spelling (e.g., Apel & Masterson, 2015).

Among those studies, Gaustad and Kelly (2004) is perhaps worth a special mention. The authors measured the morphological knowledge of deaf college students and *reading*-matched hearing middle-school students with a Split Decisions task (segmenting English words into morphemes) and a Meaningful Parts task (knowledge of affix meanings). The two tasks covered both inflectional (e.g., −*ed* and -*ing*) and derivational morphology (e.g., −*ness* and *sub*-). While there was no significant group difference for inflectional suffixes (Level 1 morphemes), the deaf college students' performance on derivational affixes (Level 2 morphemes; and Level 3 roots as well) was significantly lower than that of the middle-school students. These findings seem to suggest that derivation is much more challenging than inflection for DHH students; and compared to inflection, derivation may have a stronger and long-lasting impact on DHH students' reading development.

To what extent MA and its component skills *correlate* with different reading abilities and how it predicts reading development in DHH students, however, have remained unclear. In Trussell and Easterbrooks' (2017) systematic review of studies on morphological knowledge in DHH students, among the 16 included studies, nine were categorized as "causal-comparative" in that morphological knowledge was compared between DHH students and students of other backgrounds. Four were intervention studies targeting DHH students' morphological skills. The predominance of these two types of studies perhaps reflects researchers' strong interest in identifying DHH students' learning and developmental needs and finding strategies to support those needs. This also seems to coincide with a strong interest recently in understanding and researching DHH students' linguistic resources, notably metalinguistic insights in a sign language, and capitalizing on these resources such as through a translanguaging approach, to promote their literacy development and academic learning (e.g., Holcomb, 2023; Scott & Cohen, 2023). In sharp contrast to these two types of studies, only two studies on morphology and reading were correlational. Trussell and Easterbrooks concluded by pointing out that because of the inclusion of both intervention and non-intervention studies, they could not conduct a meta-analysis.

The Present Review and Meta-Analysis

Trussell and Easterbrooks' (2017) systematic review may reflect the limited literature of correlation studies on MA and reading in DHH students. Nonetheless, there are several reasons why another review, including a meta-analysis of correlation coefficients, is warranted. First, that review only focused on English, which means studies on other languages could have been missed. Second, it only included published journal articles. "Grey" literature, such as doctoral dissertations, which were argued as an important source of information on research and practice in reading and d/Deaf education (e.g., Andrews et al., 2015), was not included. Finally, the review covered articles published from 1970 to 2015. From 2015 to present, a further number of studies have been published on MA and reading in diverse groups of (hearing) readers, which means that more studies could have been reported with a focus on DHH students as well. A meta-analysis on DHH students, in comparison to those on general reader groups, seems particularly urgent, because the sample size in primary studies on DHH students is typically very small, which could limit the reliability and external validity of statistical inferences. (Quantitative) meta-analysis, which aims to pool study samples and generate weighted mean estimates of effect sizes, could produce more robust evidence on the relationship of MA with reading abilities and more nuanced understandings about the relationship through moderator analysis to shed light on evidence-based strategies for morphological and reading instruction.

The present article thus aims to fill this gap and achieve two main goals: to provide a scoping review of studies on correlations between MA and reading-related abilities in DHH students, and to conduct a meta-analysis on the correlations in those studies. The review and meta-analysis were guided by the following three questions.

1) What are the major study features of those that examined correlations of MA with one or more reading-related abilities in DHH students?
2) To what extent is MA correlated with word reading, vocabulary knowledge, and reading comprehension in DHH students?
3) How may the magnitude of correlations of MA with different reading-related abilities differ as a function of various reader-intrinsic and extrinsic factors?

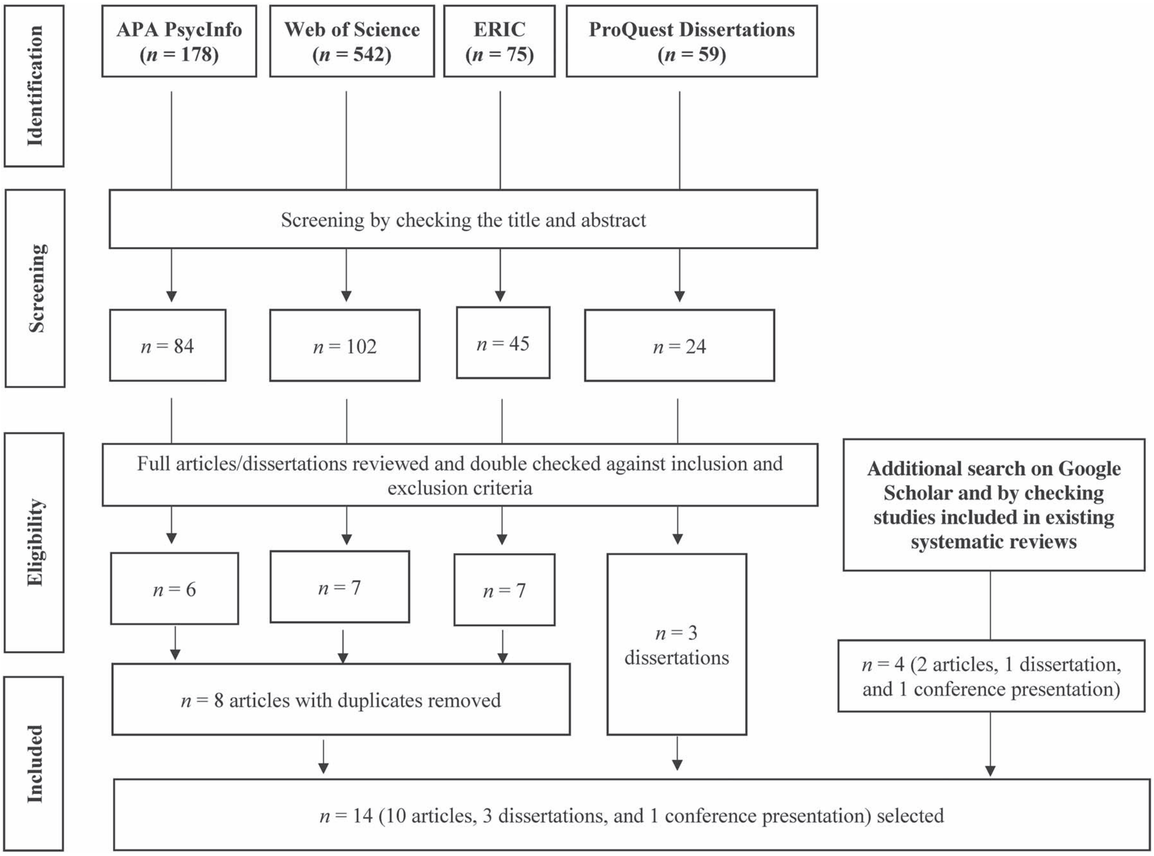

Figure 1. A flow chart showing the process of searching, screening, and selecting entries.

Method

Literature Search, Screening, and Inclusion/Exclusion Criteria

We conducted systematic literature searches, focusing on two major types of outputs, including published peer-reviewed journal articles and unpublished doctoral dissertations. The search for journal articles was conducted on three major databases, including *APA PsycINFO*, *Web of Science*, and *ERIC*. For dissertations, we searched *ProQuest Dissertations & Theses Global*. To supplement these searches, we also searched Google Scholar and referred to existing reviews on morphology and literacy in DHH students (e.g., Cannon & Trussell, 2021; Trussell & Easterbrooks, 2017). For all searches, the same set of terms was applied: ("morphological awareness" OR "morphological knowledge" OR "morphology" OR "morpheme") AND ("deaf" OR "hard of hearing" OR "hearing loss"). All searches were restricted to outputs presented in English and produced from January 1, 2000 to January 31, 2023.

Figure 1 shows the process of the initial searches to the screening and selection of studies for the present scoping review and meta-analysis. All initially searched results were subsequently screened by the first author based on the reading of the title and the abstract of each entry, to exclude the following types of work: literature reviews, editorials, qualitative outputs (e.g., a case study), experimental or causal-comparative studies that did not involve any correlations, etc. The remaining entries were further checked for eligibility by reading the full text against the following two inclusion/exclusion criteria.

First, the study must include a measure on MA and at least one of the three reading-related abilities defined for this review, that is, word reading, vocabulary knowledge, and reading comprehension. These reading-related abilities, as discussed earlier in this paper, all have important morphological underpinnings theoretically. They are also commonly meta-analyzed for MA in the literature (e.g., A. P. Goodwin & Ahn, 2013; Ke et al., 2021; Lee et al., 2023; Ruan et al., 2018). MA is defined as the ability to manipulate morphemes or knowledge of morphological structures of words. Tasks focused on morphological processing and response latency were excluded. Word reading is defined as decoding or recognition of individual, isolated words and may be focused on basic accuracy or fluency. Reading comprehension refers to the understanding of linguistic units larger than individual words including sentence or passage reading and comprehension. Finally, vocabulary knowledge is defined as the knowledge of meanings of words in a spoken language. Vocabulary knowledge is language-related but is often conceptualized as a reading-related competence as well because of its strong implication on reading development especially comprehension (see, for example, the meta-analysis in Lee et al., 2023). Second, the study must report at least one correlation of MA with one of the three reading-related variables. A small number of studies that were correlation-based but did not report such a correlation(s) were excluded. The final database (see Table 1) included 14 outputs (10 articles, 3 doctoral dissertations, and 1 conference presentation) ($k = 14$, $N = 556$).

Coding Procedure

Coding correlations

For most studies, the coding of correlations was very straightforward, because the correlation of MA with a reading outcome was clearly reported. For a few studies, the coding was more

Table 1. Studies on morphological awareness as a correlate of reading abilities

Study	Sample size	Context, language & code	Age/reading stage & code	Degree of HL & code	Participant background	MA task & code	WR task & code	VK task & code	RC task & code	Output type & code
AlMusawi, 2014	34	· Kuwait · Arabic · Code: non-alphabetic	· Age *M* = 7 years 6 months (range 70 to 112 months) · Code: beginning	· All prelingually deaf or deafness occurring at an early age; age of diagnosis unreported · HA (*N* = 18); CI (*N* = 16); age of fitting unreported · Degree of HL unreported · Aided hearing level unreported · Code: unknown	· Participants recruited from all available deaf specialist schools and units · Spoken language as the main mode of communication · All orally educated · No other deficits	· Judgment of morphological relationships; and pseudo-word production task · Codes: oral; mixed (judgment & production); mixed (inflection & derivation)	· Reading aloud words presented in vowelized orthography · *r* = .254 · Code: accuracy	N.A.	· Reading aloud a passage and then answering some comprehension questions verbally · *r* = .295 · Code: passage	· Doctoral dissertation · Code: unpublished
Bastien et al., 2006	37	· Canada · French · Code: alphabetic	· Age *M* = 31.8 years (range 19 to 53) · Code: advanced	· Deafness diagnosed before age 3 · HA or CI fitting unreported · Degree of HL unreported · Aided hearing level unreported · Code: unknown	· Born in Quebec or arrived early · Fluent user of Quebec Sign Language	· Plausibility judgment task by choosing which of two pseudo words is more likely to be a French word · Codes: written; judgment; derivation	N.A.	· LÉA/Yes-No word judgment test · *r* = .687 · Code: written	· Zigzag test where participants read two elementary-level texts of about 100 words each · *r* = .604 · Code: passage	· Conference presentation · Code: unpublished
Berthiaume & Daigle, 2014	21	· Canada · French · Code: alphabetic	· Age *M* = 11.0 years · Code: intermediate	· All prelingually deaf · HA (*N* = 6); CI (*N* = 15) (many mentioned not using them); age of fitting unreported · HL of at least 70 dB in the better ear · Aided hearing level unreported (many users reported CI did not increase auditory perception) · Code: severe to profound	· Varied home oral French use except for one · All using Quebec Sign Language as the main mode of communication · *N* = 2 regular school; *N* = 16 special schools or classes using a bilingual approach; *N* = 3 classes using an oral approach · No other deficits	· Plausibility judgment task; decomposition task · Codes: written; judgment; derivation	N.A.	N.A.	· K-ABC reading comprehension subtest · *r* = .580 · Code: passage	· Journal article · Code: published
Bharadwaj & Barlow, 2020	17	· USA · English · Code: alphabetic	· Age *M* = 9.4 years (range 8–11 years) · Code: intermediate	· Bilateral, prelingual HL; age of identification: *M* = .98 · CI (*N* = 8); HA (*N* = 9); age of fitting: CI *M* = 1.46; HA *M* = 2.27 · *N* = 9 moderate to moderately severe; *N* = 8 severe to profound · Aided hearing level unreported · Code: mild to moderately severe	· Attended a private, oral school for the deaf · Listening and spoken language for communication · Four families with Spanish as the home language	· Subtest of Comprehensive Assessment of Spoken Language focused on assessing knowledge of grammatical morphemes with an analogy task · Codes: oral; judgment; inflection	· Nonword reading/decoding subtest of the Test of Integrated Language and Literacy Skills · *r* = .510 · Code: accuracy	N.A.	· Passage comprehension subtest of the Woodcock Reading Mastery Test III · *r* = .690 · Code: passage	· Journal article · Code: published

(continued)

Table 1. Continued

Study	Sample size	Context, language & code	Age/reading stage & code	Degree of HL & code	Participant background	MA task & code	WR task & code	VK task & code	RC task & code	Output type & code
Chan, 2023	28	· Taiwan · Chinese · Code: non-alphabetic	· First grade; age $M = 6.0$ years · Code: beginning	· Bilateral, congenital HL; age of identification: $M = 1.87$ · HA ($N = 20$); CI ($N = 8$); age of fitting $M = 2.27$ · $N = 17$ mild to moderately severe; $N = 11$ severe or profound · Aided hearing level $M = 24.81$ dB · Code: mild to moderately severe	· Participants recruited from centers of a hearing foundation · Chinese spoken at home or school · Child using spoken language rather than sign language · No other disorders	· Word construction task where participants say loud a novel word based on the morphological structure of a familiar compound word · Codes: oral; production; compound	N.A.	· Chinese PPVT where participants choose a picture that best fits the meaning of a word heard · $r = .860$ · Code: oral	· Standardized paper-and-pencil sentence and passage comprehension test with multiple choices questions ·$r = .800$ · Code: mixed (passage & sentence)	· Journal article · Code: published
Chan & Yang, 2018	25	· Taiwan · Chinese · Code: non-alphabetic	· Age $M = 95$ months · Code: beginning	· HL at birth · HA ($N = 17$); CI ($N = 8$): age of fitting unreported · HL of unaided better ear: $M = 72.6$ dB; $N = 9$ mild to moderately severe; $N = 16$ severe or profound · Aided hearing level: normal to moderate · Code: severe to profound	· Participants recruited from children's hearing foundation · Mainstreamed and using spoken language in school · No other known disorders	· Word construction task in which participants are asked to say loud a novel word based on the morphological structure of a familiar compound word · Codes: oral; production; compound	· Chinese character recognition by writing down the Mandarin phonetic alphabets for characters presented in decreasing frequency · $r = .570$ · Code: accuracy	· Receptive vocabulary test by choosing one picture that best fits the meaning of a word heard · $r = .790$ · Code: oral	· Standardized paper-and-pencil sentence and passage comprehension test with multiple choices questions · $r = .710$ · Code: mixed (passage & sentence)	· Journal article · Code: published
Chen, 2005[a]	40	· Taiwan · Chinese · Code: non-alphabetic	· Age $M = 5.5$ (range 5–8) years ·Code: beginning	· Prelingually hearing loss; age of identification unreported · HA ($N = 20$); CI ($N = 20$); age of fitting unreported ·HL all severe to profound · Aided hearing level: about 40 dB ·Code: severe to profound	· Participants recruited from early intervention institutes · Aural-oral methodology used for early intervention · No other disabilities	· Discriminating radical form; radical meaning; character selection for homophone discrimination · Codes: written; judgment; mixed (homophone/ homograph & radical)	N.A.	· Choosing one picture that best fits the meaning of a word heard · $r = .194$ · Code: oral	· Sentence reading task where participants point out a picture that explains the meaning of a sentence read · $r = .616$ · Code: sentence	· Doctoral dissertation · Code: unpublished
Ching & Nunes, 2015	32	· Hong Kong · Chinese · Code: non-alphabetic	· Age $M = 9.8$ (range 7.9–11.6) years · Code: intermediate	· Deaf at birth · HA ($N = 22$); CI ($N = 10$); age of fitting: most 12–35 months for HA; 12–47 months for CI · $N = 20$ moderate to moderately severe; $N = 12$ severe to profound · Aided hearing level unreported · Code: moderate to moderately severe	· Using hearing device regularly · $N = 29$ L1 Cantonese · $N = 18$ from mainstream schools; $N = 8$ mainstream schools with a DHH specialist unit; $N = 6$ DHH schools · No specific learning disabilities	· Morpheme identification focused on homophone/homograph discrimination; and morpheme construction on producing words with a given morpheme · Codes: oral; mixed (judgment & production); homophone/ homograph	· Word recognition by pointing to a picture that explains the meaning of a word · $r = .535$ · Code: accuracy	N.A.	N.A.	· Journal article · Code: published

(continued)

Table 1. Continued

Study	Sample size	Context, language & code	Age/reading stage & code	Degree of HL & code	Participant background	MA task & code	WR task & code	VK task & code	RC task & code	Output type & code
Kelly & Gaustad, 2007[b]	55	· USA · English · Code: alphabetic	· College students · Code: advanced	· Age of HL identification unreported · CI or HA fitting unreported · Degree of HL $M = 98.9$ dB · Aided hearing level unreported · Code: severe to profound	· DHH students at the National Technical Institute for the Deaf, Rochester Institute of Technology	· Split Decisions test focused on morphological segmentation; and Meaningful Parts test measuring knowledge of affixes · Codes: written; judgment; mixed (inflection & derivation)	N.A.	N.A.	· California Achievement Test for Comprehension · $r = .420$ · Code: passage	· Journal article · Code: published
López-Higes et al., 2015	57	· Spain · Spanish · Code: alphabetic	· Age range: 8–12 years ($M =$ about 120 months) · Code: intermediate	· HL diagnosed in prelingual phase (before 24 months) · CI ($N = 38$); age of fitting: half before 24 months; half between 24 months and 5 years · Degree pf HL: severe or profound · Aided hearing level unreported · Code: severe to profound	· Primary school students (no other information presented)	· Selecting an appropriate inflected or derived form from given choices to complete a sentence · Code: written; judgment; mixed (inflection & derivation)	N.A.	N.A.	· Grammatical structure subtest of PROLEC-R, a standardized reading test where participants select a picture to represent the meaning of a sentence · $r = .720$ · Code: sentence	· Journal article · Code: published
Nielsen et al., 2016	17	· USA · English · Code: alphabetic	· Age range: 7.6–13.9 years (9–11 years $N = 12$) · Code: intermediate	· Age of HL diagnosis: birth to 1 year old $N = 7$; 1–2 years $N = 6$; 2–4 years $N = 4$ · HA ($N = 6$); CI ($N = 11$); age of fitting: $N = 6$ before 1st birthday; $N = 3$ before 2 years; $N = 5$ before 3 years; $N = 3$ between 3–5 years · All severe or profound except one ($N = 13$ profound) · Aided hearing level $M = 27.5$ dB (range 10–83 dB) · Code: severe to profound	· Students from a school for the deaf · Simultaneous speech and grammatically accurate sign as the method of communication used at the school; students expected to speak and sign standard English · English-speaking parents; English L1; no home ASL · No additional disabilities	· Researched-developed task where participants are asked to select an appropriate inflected or derived form of a word to complete a sentence · Codes: written; judgment; mixed (inflection & derivation)	N.A.	· Vocabulary Subtest of the Gates-MacGinitie Reading Test · $r = .622$ · Code: written	· Passage Comprehension Subtest of the Gates-MacGinitie Reading Test · $r = .523$ · Code: passage	· Journal article · Code: published
Squires, 2021[c]	15	· Canada · English · Code: alphabetic	· Age $M = 120$ months (range 93–143 months); grade $M = 4.3$ (range 2–6) · Code: intermediate	· Age of HL diagnosis $M = 30.9$ months (range birth to 7 years) · HA except one; age of fitting unreported · Degree of HL $M = 47.7$ dB (range 23.8–75.6 dB) · Aided hearing level unreported · Code: mild to moderately severe	· Participants identified by Atlantic Provinces Special Educational Authority as DHH · English L1; no use of any form of signed language · Only one child reported to have ADHD/learning difficulties	· Morphological derivation and decomposition · $r = .646$ · Codes: written; production; derivation	· Test of Word Reading Efficiency · $r = .646$ · Code: fluency	· Picture Vocabulary Subtest of the Woodcock-Johnson III tests of Achievement · $r = .826$ · Code: oral	· Passage Comprehension Subtest of the Woodcock Reading Mastery Tests III · $r = .818$ · Code: passage	· Doctoral dissertation · Code: unpublished

(continued)

Table 1. Continued

Study	Sample size	Context, language & code	Age/reading stage & code	Degree of HL & code	Participant background	MA task & code	WR task & code	VK task & code	RC task & code	Output type & code
Sun et al., 2022	133	· Mainland China · Chinese · Code: non-alphabetic	· Age $M = 13$ years 9 months (range 9 years 5 months to 18 years); grades 4–6 · Code: advanced	· Prelingual deaf; age of diagnosis unreported · HA or CI $N = 28$ (rare use); age of fitting unreported · $N = 121$ profound (others ranged from severe to moderately severe) · Aided hearing level unreported · Code: severe to profound	· All having limited or no auditory access to spoken language · All having CSL as the communication language · CSL having a prominent role in school curriculum and classrooms · No other disabilities	· Pseudo-homophone detection task · Codes: written; judgment; homophone/ homograph	· Accuracy: students signed to explain words · Fluency: students draw boundaries between words in a chain/chunk · $r = .530$ · Code: mixed (accuracy & fluency)	N.A.	N.A.	· Journal article · Code: published
Wang et al., 2017[d]	45	· USA · English · Code: alphabetic	· Grade $M = 5.4$ (range 3–8); age $M = 1.7$ (range 8–14) years · Code: intermediate	· Age of HL diagnosis unreported · HA ($N = 23$); CI ($N = 22$); age of fitting unreported · Degree of HL: at least 80 dB for all (70–125 for right ear; 67–128 for leaf ear) · Aided hearing level unreported · Code: severe to profound	· An urban school for DHH students adhering to a Total Communication philosophy · ASL or Simultaneous Communication as preferred method of communication · Four had additional disabilities · Primary/home language $N = 26$ English; $N = 15$ Spanish	· Morphological Knowledge Task: three separate tasks on judgement, production, and decomposition · Codes: written; mixed (judgment & production); derivation	· Test of Silent Word Reading Fluency (TSWRF) · $r = .905$ · Code: fluency	N.A.	· Passage Comprehension Subtest of the Woodcock Johnson III · $r = .890$ · Code: passage	· Journal article · Code: published

Note. DHH = d/Deaf or hard of hearing; HA = hearing aid; CI = Cochlear Implant; HL = hearing loss; L1 = first language; ASL = American Sign Language; CSL = Chinese Sign Language; MA = morphological awareness; WR = word reading; VK = vocabulary knowledge; RC = reading comprehension [a]This was an intervention study with correlations reported. Pre-instruction/intervention correlations are extracted for this meta-analysis. [b]Different sets of correlations were reported on two overlapping samples. Extracted correlations are based on the larger sample ($N = 55$) who took the NTID Mathematics Placement Test and the California Reading Test for Comprehension. [c]This is based on Study 2. Studies 1 and 2 involved the same participants. Study 2 correlations are extracted because this study involved more reading variables. [d]This duplicates Falk (2017), a doctoral dissertation that reported the same findings. The dissertation is excluded for this review and meta-analysis. Falk was a co-author of this study.

nuanced. For example, if a study included more than one task for MA and/or a reading-related variable and consequently reported multiple correlations between them, we followed previous meta-analyses (e.g., Ruan et al., 2018) to calculate the simple average of these correlations. Chen (2005) was an intervention study where correlations between MA and reading outcomes were reported on both pre- and post-test results. We extracted the pre-intervention correlations. Kelly and Gaustad (2007) reported two sets of correlations based on two overlapping samples. We extracted the correlations based on the larger sample.

Moderators and their coding

For each study, the following set of moderators was also coded. The coding results, together with those on correlations, are presented in Table 1 (see also Appendix S1).

Language

Language was coded as alphabetic (i.e., English, French, and Spanish) or non-alphabetic (i.e., Chinese and Arabic).

Degree of Hearing Loss (HL)

Degree of HL was coded into two ordinal categories based on the Pure-Tone Average reported on the better unaided ear: mild to moderately severe (20 dB–70 dB) and severe to profound (71 dB and above). For studies where participants showed a range of degrees of HL, we referred to the proportion of participants belonging to the two categories. If the majority (defined as over 50% of the sample) were reported to belong to one of the two categories, the study would be coded as such.

Age/Reading Stage

Based on A. P. Goodwin and Ahn (2013) and Ruan et al. (2018), we coded participants into one of the three groups based on broad phases of reading development. We included adults as well as school-aged students to make the review more inclusive. If a study involved students across any age range, we decided whether readers of a particular code were the majority group (larger than 50% of the sample) and coded them accordingly.

- Beginning ($k = 4$): grade 2 or below (about 8 years or younger)
- Intermediate ($k = 7$): grades 3–5 (about 9–11 years old)
- Advanced ($k = 3$): grade 6 or above (12 years or older)

MA Task Type

Following previous meta-analyses (Ke et al., 2021; Lee et al., 2023; Ruan et al., 2018), we coded MA for three task types: 1) oral versus written; 2) judgment (e.g., making a yes/no judgment on morphological relations or selecting a choice from given options) versus production (e.g., generating a derived word based on the base word given to complete a sentence); 3) morphological structure/feature, which, depending on the language, may include inflection, compounding, derivation, homophone/homograph, etc. If multiple features were involved in a MA task(s), they would be coded as mixed in those features' combination.

Reading-Related Task

Word reading was coded as either accuracy and fluency, vocabulary knowledge as oral or written, and reading comprehension as sentence or passage comprehension. A study would be coded as mixed if the task(s) covered both aspects of a moderator.

Type of Output

The published journal articles were coded as published whereas the doctoral dissertations and the conference presentation were coded as unpublished.

Coder Reliability

The first and the second author coded all 14 studies separately and then met up to compare the results and resolve any discrepancies. For the coding of correlations between MA and word reading ($k = 7$), they initially agreed on all *r*s except for one study. The coding results for correlations between MA and vocabulary ($k = 6$) showed full agreement. For the coding of correlations between MA and reading comprehension ($k = 12$), the results converged except for one study. The coding of moderators showed 100% agreement.

Procedure of Meta-Analysis

All meta-analyses were conducted with the Comprehensive Meta-Analysis (CMA 3.0) program (Borenstein, 2022) (http://www.Meta-Analysis.com). To estimate the mean correlation of MA with each reading variable, a random-effects model was applied, because it, as opposed to a fixed-effects model, assumes that study variations are systematic rather than due to sampling error. For each relationship, both the average correlation estimate and 95% Confidence Interval were calculated. Sensitivity analysis was also conducted to examine how the removal of an individual study would impact the overall correlation (see Appendix S3). We also performed the Q test for heterogeneity to estimate whether the variation in the effect sizes was significant for each relationship (Hedges & Olkin, 2014). I^2 was also reported for each relationship. It refers to the percentage of the variability among effect sizes (e.g., correlations of MA with word reading) that is caused by real heterogeneity rather than by sampling error. There are no agreed cutoff values for interpreting the actual size of I^2, but a general guide is that 25%, 50%, and 75% represent a small, moderate, and high level of heterogeneity, respectively (Higgins et al., 2003).

In addition to moderator analysis on published versus unpublished outputs, we also checked whether retrieval bias was present for each relationship through visually inspecting a funnel plot. A plot, in the absence of retrieval bias, should be expected to display the effect sizes in the form of an inverted funnel and with no effect sizes missing on either size of the mean. The funnel plots presented in Appendix S3 seem to suggest a lack of notable retrieval bias for any of the three relationships of MA with reading variables. For moderator analysis, we only included those categories or codes where there were two or more effect sizes. For each moderator, a Q test, which is like an *F* test in the analysis of variance, was conducted to estimate the degree of difference between the subsets of effect sizes defined by the moderator. A significant Q test result means that there is a statistically significant effect of a moderator, or in other words, a significant between-group difference in the magnitude of the correlations for that moderator.

A Scoping Review of Correlation Studies on MA and Reading

Table 1 summarizes the 14 studies included for this review and the subsequent meta-analysis. The studies were conducted with DHH students in seven countries/regions, mostly in the United States ($k = 4$), Canada ($k = 3$), and Taiwan ($k = 3$). They mostly focused on English ($k = 5$) and Chinese ($k = 5$), but also covered

French, Arabic, and Spanish. The sample size ranged from 15 to 133 ($M = 40$). Twelve studies (about 86%) focused on K-12 or school-aged students, with the other two on adults or university students. Participants across the 14 studies showed a wide range of age, with the youngest sample having a mean age of 5.5 years and the oldest 31.8 years.

In most studies, participants were congenital or prelingually deaf or the detection of HL occurred at an early age. Five studies additionally provided the specific age of HL detection. Among the 12 studies where information was provided on the fitting of hearing devices, all participants were reported to be fitted with HA or CI. The age of device fitting, however, was only reported in five studies and also showed a wide range, from as early as before the first birthday to five years old. Specific degree of HL was reported in 12 studies. Only four studies additionally reported their participants' device-aided hearing level. Table 1 also shows that for most studies, participants studied in mainstream schools and were orally educated, and used spoken language as the main language or mode of communication. Only in a few studies were participants reported to use a sign language as their preferred method of communication. While for most studies, students' home language was the societal spoken language (e.g., English in the United States or Cantonese in Hong Kong), two studies (Bharadwaj & Barlow, 2020; Wang et al., 2017) noted on the inclusion of a small number of students whose primary or home language (e.g., Spanish in the United States) was neither a societal spoken language nor a sign language.

Table 1 shows that 7, 6, and 12 of the 14 studies included word reading, vocabulary knowledge, and reading comprehension, respectively, as a correlate of MA. In only two studies were all three reading-related variables measured. Table 1 further summarizes the different types of tasks that the studies employed to measure MA and reading-related abilities.

For the measurement of MA, nine studies employed a written task(s) whereas the other five used an oral task(s). The task(s) in eight studies was based on morphological judgment, whereas in three studies a production task(s) was used and in the remaining three studies, the task(s) involved both judgment and production. MA tasks collectively covered a range of morphological features, which also seemed to show some language-specific distinctions. For example, inflection and/or derivation were the focus in nine studies ($k = 4$ for derivation; $k = 1$ for inflection; and $k = 4$ for mixed/inflection and derivation), which, with one exception (i.e., Arabic in AlMusawi, 2014), were all about alphabetic languages characterized by salient affixational morphology including English ($k = 5$), French ($k = 2$), and Spanish ($k = 1$). For the five studies on Chinese, the MA tasks focused on compounding ($k = 2$) and homograph/homophone discrimination ($k = 3$).

For the reading-related tasks, among the seven studies where word reading was measured, four focused on accuracy, two on fluency, and an additional one on both. Vocabulary knowledge was a correlate of MA in six studies, which all focused on receptive knowledge except Squires (2021). Four studies employed an oral vocabulary measure, typically asking participants to match a word heard with a picture. A large majority of the studies ($k = 12$) had reading comprehension as a correlate of MA. Eight of them focused on passage comprehension; in two studies, the measure(s) covered both sentence and passage comprehension; and in another two studies, the focus was on sentence comprehension only. The specific tasks for measuring reading comprehension, and other variables, can be seen in Table 1.

Results of Meta-Analysis

MA and Word Reading

Seven effect sizes that involved 301 ($M = 43$; range: 15–133) DHH students in total were meta-analyzed on the relationship between MA and word reading. As shown in Table 2, the weighted mean correlation was significant, $r = .610$ (95% CI: .374, .772), $z = 4.397$, $p < .001$. Based on Cohen (1988), this correlation was high ($r = .10$, .30, and .50 representing low, moderate, and high effect size, respectively). The variation in the effect sizes was significant, $Q = 35.091$, $p < .001$, and $I^2 = 82.902\%$, which indicates a high level of variability (Higgins et al., 2003). The Forest plots for this relationship and the other two can be found in Appendix S2.

Table 3 shows further the results of moderator analysis. A significant effect was found for two moderators, that is, language and word reading task. The correlation was significantly stronger for alphabetic ($r = .777$; high) than non-alphabetic languages ($r = .482$; moderate), $Q = 4.329$, $p = .037$. It was also significantly stronger for word reading fluency ($r = .848$; high) than accuracy ($r = .467$; moderate), $Q = 8.765$, $p = .003$. A significant effect did not surface for other moderators. Assessing the magnitude of the correlations, however, showed some interesting findings on the different subsets of effect sizes of a moderator. For example, the correlation was high in size for intermediate readers but moderate for beginning readers. Written MA tasks appeared to produce a higher correlation; for oral MA tasks, the mean correlation was moderate. Also notably, the correlation was high for both degrees of HL, which seems to suggest that MA is a strong underpinning of word reading, disregarding DHH students' unaided hearing level.

MA and Vocabulary Knowledge

Six effect sizes, which were comprised of 142 ($M = 24$; range: 15–37) DHH students in total, were meta-analyzed on the relationship between MA and vocabulary knowledge. As shown in Table 2, the weighted mean correlation was high and significant, $r = .712$ (95% CI: .527, .832), $z = 5.719$, $p < .001$. There was also significant and a moderate level of variability in those effect sizes, $Q = 14.362$, $p = .013$, and $I^2 = 65.186\%$.

Moderator analysis, as shown in Table 4, revealed that only MA Task II, that is, judgment versus production, had a significant effect. Specifically, the correlation was significantly higher for production tasks ($r = .829$) than for judgment tasks ($r = .557$), $Q = 6.786$, $p = .009$. For both types of tasks, the correlation was high. While none of the other moderator effects was significant, it is notable that for each moderator, the mean correlation was consistently high for each subset of effect sizes of these moderators. Taken together, these findings suggest that MA is a reliable and strong correlate of vocabulary knowledge, disregarding languages, students' HL conditions, and reading stages, as well as tasks for measuring MA or vocabulary knowledge.

MA and Reading Comprehension

The meta-analysis for MA and reading comprehension included 12 effect sizes, which altogether involved 371 ($M = 31$; range: 15–57) DHH students. As shown in Table 2, the weighted mean correlation was high and significant, $r = .669$ (95% CI: .542, .766), $z = 7.861$, $p < .001$. There was also significant and a moderate level of variability in those effect sizes, $Q = 36.314$, $p < .001$, and $I^2 = 69.709\%$.

Table 5 presents the results of the moderator analysis. A notable finding was perhaps that derivation-focused MA tasks ($r = .758$) appeared to produce a higher correlation, with marginal significance, than did those that had a mixed focus on derivation and inflection ($r = .513$), $Q = 2.870$, $p = .090$. While no moderator

Table 2. Mean correlations between MA and reading abilities

Relationship	*k*	*r* [95% CI]	Z-value (*p*)	Q Test for heterogeneity (*p*)	I^2 (%)	τ^2
MA-WR	7	0.610 [.374, .772]	4.397 (<.001)	35.091 (<.001)	82.902	0.143
MA-VK	6	0.712 [.527, .832]	5.719 (<.001)	14.362 (.013)	65.186	0.093
MA-RC	12	0.669 [.542, .766]	7.861 (<.001)	36.314 (<.001)	69.709	0.084

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

Table 3. Moderator analysis results for the relationship between MA and WR

Moderator	Subgroups[a]	Number of correlations (*k*)	Correlation (*r*)	95% CI	Z-value (*p*)	Heterogeneity (Q test)
Language	Alphabetic	3	0.777	0.574, .890	5.304 (<.001)	4.329 (*p* = .037)
	Non-Alphabetic	4	0.482	0.229, .674	3.520 (<.001)	
Age/Grade	Beginning	2	0.420	−0.195, .798	1.361 (.174)	1.142 (*p* = .285)
	Intermediate	4	0.708	0.392, .874	3.692 (<.001)	
HL Degree	Mild to moderately severe	3	0.564	0.083, .832	2.255 (.024)	0.504 (*p* = .478)
	Severe to profound	3	0.722	0.381, .890	3.498 (<.001)	
MA Task I	Oral	4	0.472	0.072, .741	2.280 (.023)	1.731 (*p* = .188)
	Written	3	0.743	0.432, .896	3.796 (<.001)	
MA Task II[b]	Judgment	2	0.521	−0.156, .865	1.541 (.123)	0.199 (*p* = .905)
	Judgment & production	3	0.660	0.197, .883	2.618 (.009)	
Production	2	0.607	−0.065, .900	1.793 (.073)		
WR Task	Accuracy	4	0.467	0.218, .658	3.494 (<.001)	8.765 (*p* = .003)
	Fluency	2	0.848	0.689, .929	6.082 (<.001)	
Output Type	Published	5	0.659	0.391, .823	4.108 (<.001)	0.676 (*p* = .411)
	Unpublished	2	0.449	−0.144, .805	1.506 (.132)	

Note. MA = morphological awareness; WR = Word Reading; HL = hearing loss [a]Heterogeneity results based on subgroups with two or more effect sizes only [b]MA Task III based on morphological feature was not tested, because homograph/homophone and derivation, the only two features with more than one effect size, happened to focus on Chinese and English, respectively.

Table 4. Moderator analysis results for the relationship between MA and VK

Moderator	Subgroups[a]	Number of correlations (*k*)	Correlation (*r*)	95% CI	Z-value (*p*)	Heterogeneity (Q test)
Language	Alphabetic	3	0.719	0.388, .885	3.578 (<.001)	0.008 (*p* = .930)
	Non-Alphabetic	3	0.703	0.373, .875	3.556 (<.001)	
Age/Grade	Beginning	3	0.701	0.293, .893	3.003 (.003)	0.028 (*p* = .868)
	Intermediate	2	0.738	0.210, .933	2.530 (.011)	
HL Degree	Mild to moderately severe	2	0.846	0.612, .944	4.596 (<.001)	2.631 (*p* = .105)
	Severe to profound	3	0.590	0.241, .804	3.075 (.002)	
MA Task I	Oral	2	0.829	0.637, .924	5.373 (<.001)	2.761 (*p* = .097)
	Written	4	0.620	0.379, .783	4.347 (<.001)	
MA Task II[b]	Judgment	3	0.557	0.324, .726	4.219 (<.001)	6.786 (*p* = .009)
	Production	3	0.829	0.709, .902	7.740 (<.001)	
VK Task	Oral	4	0.735	0.478, .876	4.392 (<.001)	0.164 (*p* = .686)
	Written	2	0.660	0.208, .879	2.673 (.008)	
Output Type	Published	3	0.783	0.562, .899	4.958 (<.001)	1.170 (*p* = .279)
	Unpublished	3	0.621	0.297, .817	3.387 (.001)	

Note. MA = morphological awareness; VK = vocabulary knowledge; HL = hearing loss [a]Heterogeneity results based on subgroups with two or more effect sizes only. [b]MA Task III based on morphological feature was not tested, because compounding and derivation, the only two features with more than one effect size, happened to focus on Chinese and English, respectively.

was found to have a significant effect, the correlation was, as in the cases of the other two reading variables, high in size across subsets of effect sizes. These findings provide robust evidence of the importance of MA for reading comprehension.

Discussion

Scope of Studies on MA as a Correlate of Reading

To answer RQ1, 14 studies were identified to report on the correlations of MA with reading abilities. Compared with the very limited representation ($k = 2$) in Trussell and Easterbrooks' (2017) systematic review, the body of literature synthesized in this review clearly shows major development of interest and research on MA and reading in DHH students. This of course does not deny the fact that the research is still limited. Lee et al.'s (2023) recent meta-analysis, for example, included 582, 723, and 394 effect sizes for the correlation of MA with vocabulary knowledge, word reading, and reading comprehension, respectively. The sample size of the 14 included studies was arguably small ($M = 40$; range: 15–133). This may not be surprising, considering that DHH students are a minority group in developing readers, and studies often also need to consider other criteria for inclusion of them as

Table 5. Moderator analysis results for the relationship between MA and RC

Moderator	Subgroups[a]	Number of correlations (*k*)	Correlation (*r*)	95% CI	Z-value (*p*)	Heterogeneity (Q test)
Language	Alphabetic	8	0.686	0.526, .799	6.443 (<.001)	0.176 (*p* = .675)
	Non-Alphabetic	4	0.632	0.364, .803	4.022 (<.001)	
Age/Grade	Beginning	4	0.631	0.397, .788	4.512 (<.001)	2.629 (*p* = .269)
	Intermediate	6	0.742	0.596, .841	6.954 (<.001)	
	Advanced	2	0.513	0.152, .753	2.684 (.007)	
HL Degree	Unknown	2	0.466	0.051, .743	2.181 (.029)	2.852 (*p* = .240)
	Mild to moderately severe	3	0.776	0.547, .897	4.818 (<.001)	0.716 (*p* = .397)[b]
	Severe to profound	7	0.675	0.515, .790	6.411 (<.001)	
MA Task I	Oral	4	0.648	0.384, .815	4.116 (<.001)	0.053 (*p* = .817)
	Written	8	0.678	0.515, .794	6.327 (<.001)	
MA Task II	Judgment	7	0.600	0.404, .743	5.138 (<.001)	1.971 (*p* = .373)
	Judgment & production	2	0.708	0.396, .874	3.724 (<.001)	
	Production	3	0.777	0.549, .898	4.828 (<.001)	
MA Task III	Derivation	4	0.758	0.562, .873	5.460 (<.001)	2.870 (*p* = .090)[c]
	Inflection & derivation	4	0.513	0.223, .719	3.273 (.001)	
RC Task	Passage	8	0.639	0.452, .772	5.511 (<.001)	0.616 (*p* = .735)
	Passage & sentence	2	0.759	0.431, .910	3.651 (<.001)	
	Sentence	2	0.678	0.295, .874	3.104 (.002)	
Output Type	Published	8	0.700	0.555, .804	7.018 (<.001)	0.739 (*p* = .390)
	Unpublished	4	0.592	0.316, .775	3.772 (<.001)	

Note. MA = morphological awareness; RC = reading comprehension; HL = hearing loss [a]Heterogeneity results based on subgroups with two or more effect sizes only. [b]Heterogeneity results excluding the "unknown" subgroup. [c]Compounding was not analyzed, because its two effect sizes happened to focus on Chinese only.

participants, such as no additional education needs or disabilities (see Table 1).

Another notable feature was that 5 languages of different orthographies (Arabic, Chinese, English, French, and Spanish) were covered in the 14 studies, which collectively also covered all important aspects of reading (word reading and fluency, vocabulary knowledge, and reading comprehension) that have been a focus of studies on other groups of typical literacy learners (Ke et al., 2021; Lee et al., 2023; Ruan et al., 2018). The 14 studies also employed a wide range of tasks to measure participants' MA and reading-related abilities. Participants also covered a wide range of students at different stages of reading or education. Many of the included studies, in addition to examining how MA correlated or predicted reading abilities, also compared the level of MA and reading performance in DHH and age-matched hearing students. More important, many also purposefully compared the two groups on the pattern of correlations between MA and reading, sometimes with other variables such as cognition (e.g., working memory) and PA (e.g., Bharadwaj & Barlow, 2020; Squires, 2021), to explore how reading and its underlying processes may show qualitative similarities and/or quantitative differences between the two groups (refer to Paul et al., 2013 for discussions on the QSH). These are all very notable strengths in the research on MA and reading in DHH students, even though, as discussed later, there is still much to expand the current literature.

In what follows, we answer RQs 2 and 3 and discuss the meta-analytic findings. Where relevant and possible with available evidence, we refer to existing meta-analytic findings on other reader groups such as (hearing) monolinguals and bilingual/L2 learners to help contextualize the interpretation of MA as a correlate of reading in DHH students. Considering that most DHH students (e.g., 80–85% in the United Kingdom and the United States) nowadays study in mainstream classrooms together with their typical hearing peers, a contextualized interpretation will help generate nuanced understandings about DHH students' common and distinct learning and developmental needs and shed light on instructional differentiation to promote their development of reading and academic skills.

Correlation of MA with Word Reading

The mean correlation of MA with word reading was significant and high ($r = .601$), which lends clear support to the importance of morphology in word reading for DHH students. The correlation also seems much higher than those reported in previous meta-analyses, such as $r = .49$ in Lee et al. (2023) and $r = .46$ in Ke et al. (2021). This suggests that in comparison to typical hearing monolingual and bilingual students, MA could be even more important a factor in DHH students' word reading, particularly in consideration of their reduced access to phonology (this, of course, does not mean that phonological skills are unimportant for DHH students; see Luft, 2018; Mayberry et al., 2011; Paul et al., 2013). It also seems to support Gaustad's (2000) proposal on a morphographic model of word recognition for DHH students and the importance of morphographic analysis as an important supplement or alternative to graphophonemic skills in DHH students' word reading (in this respect, it may be of particular relevance to mention the high correlation found of written MA tasks; $r = .743$; see Table 3).

The moderator analysis results provided more intriguing insights. For example, the higher correlation for word reading fluency supports the discussion earlier on quality of sub-lexical representations, chunking, and word recognition efficiency. Among previous meta-analyses on correlations between MA and reading, Ruan et al. (2018) was perhaps the only one that distinguished between word reading fluency and accuracy. For both types of word reading, and for both Chinese and English, Ruan et al. (2018) reported moderate correlations (r ranged from .368 to .461), and there did not seem to be any notable difference between the two types of reading. Given the importance of reading fluency for DHH students (Easterbrooks & Lederberg, 2021; Luckner & Urbach, 2012), the current moderator analysis result highlights the need for morphological instruction to promote that development. The finding that the correlation was significantly higher in alphabetic (r = .777) than in non-alphabetic languages (r = .482) seems to corroborate Ruan et al.'s (2018) that compared the relative strength of correlation of MA with reading skills in English and Chinese. To our knowledge, no primary studies have compared MA and word reading in different languages with a focus on DHH students. The present moderator analysis finding has thus filled a gap. One speculation for the stronger correlation in alphabetic languages might be that MA tasks in studies on those languages (k = 3 all being English; see Table 1) largely focused on derivation which is morphographically and morphophonologically complex, whereas in non-alphabetic languages (effect sizes happening to be largely on Chinese) the tasks were more structural in nature (i.e., lexical compounding). In other words, the relative importance of MA in word reading in different languages may coincide with studies choosing to measure the salient morphological feature in a respective language. This suggests that the cross-language difference should perhaps be interpreted with caution.

While no significant effect was found on other moderators, the magnitude of the correlations for the subsets of effect sizes of a moderator also seemed to provide some important insights. For example, the correlation was high for intermediate readers (r = .708) but moderate for beginning readers (r = .420), which suggests that developmentally the role of morphology could be stronger in word reading (perhaps especially fluency). This pattern is theoretically justifiable in accordance with phase models of reading acquisition where chunking and morpheme-based decoding happens relatively late in elementary school (Ehri, 2005). In addition, written MA tasks produced a high correlation (r = .743) whereas for oral MA tasks, the mean correlation was moderate (r = .472), which as mentioned earlier seems to particularly support morphographic analysis for DHH students' development of word reading (especially fluency) (Gaustad, 2000; Trussell & Easterbrooks, 2015). Finally, while the correlation was high in size disregarding the degree of HL, it appeared stronger for those with severe to profound HL (r = .743) than those whose HL was mild to moderately severe (r = .564). This finding is interesting because in almost all the included studies participants were fitted with HA or CI. It may imply that the device may not enable an equal level of access to phonology for DHH students with different levels of HL; as a result, compared to those with lower degrees of HL, those with severe or profound HL may tend to rely more on morphographic analysis than on graphophonemic analysis for word reading. These conjectures could not be verified based on existing research evidence. Future research is needed to examine the correlation of MA, perhaps together with that of PA, with word reading, with degree of HL, and device-aided hearing level as potential covariates and/or moderators.

Correlation of MA with Vocabulary Knowledge

The meta-analysis found a high mean correlation of MA with vocabulary (r = .712). This correlation was also higher than that reported in Lee et al.'s (2023) meta-analysis (r = .50). Perhaps in some distinctions from the results of moderator analysis discussed earlier on word reading, the correlation of MA with vocabulary knowledge was consistently high for the subsets of effect sizes of any moderator. This is strong evidence that MA is reliably important for vocabulary development disregarding language, stage of reading, and ways of assessing MA or vocabulary knowledge. Considering the great vocabulary learning needs in DHH students (Luckner & Cooke, 2010; Lund, 2016), the present finding lends clear support to an instructional focus where morphological problem-solving should be emphasized for promoting DHH students' lexical engagement and vocabulary development.

The fact that the correlation of MA with vocabulary knowledge also appeared higher than that with word reading within DHH students themselves perhaps additionally suggests that an instructional focus on DHH students' capacity for morphological problem-solving and vocabulary expansion could be more urgent than morphographic analysis for word recognition purposes. This capacity has been particularly emphasized for promoting vocabulary development and academic achievement in students from disadvantaged backgrounds, such as those from low SES families in urban schools or English Learners in the United States (see A. P. Goodwin et al., 2012; Kieffer & Lesaux, 2007; Nagy et al., 2014). The present meta-analytic finding that the mean correlation with vocabulary knowledge was significantly stronger for production MA tasks (r = .829) than for judgment tasks (r = .557) (see Table 4) perhaps further suggests that opportunities for DHH students to use knowledge of morphemes and morphological structures to actively construct words should be an essential instructional consideration.

Correlation of MA with Reading Comprehension

This meta-analysis also found a high correlation of MA with reading comprehension (r = .669). This correlation also appeared stronger than those found in earlier meta-analyses, such as Lee et al. (2023) (r = .54), Ruan et al. (2018) (r = .360 for Chinese and r = .534 for English), Tighe and Schatschneider (2016) (r =. 59 for struggling adult readers of English), as well as Ke et al. (2021) (r = .52 for L2 readers). As in the case of MA and vocabulary knowledge, the mean correlations were also all high for the subsets of effect sizes of any moderator, which suggests that the importance of MA for reading comprehension is reliable and robust, disregarding language, reading stage, and tasks for measuring MA or reading comprehension. These findings were not unexpected, given the various direct and indirect mechanisms discussed earlier in this article on the contribution of morphology to reading comprehension, particularly with references to the strong association of MA with word reading (especially fluency) and vocabulary knowledge on the one hand, and that of word reading (fluency) and vocabulary knowledge with reading comprehension on the other (Levesque et al., 2021; Nagy et al., 2014).

Among all the moderators, the finding on morphological features of MA tasks seems to deserve some special attention. The moderator analysis for MA task III focused on comparing derivation and inflection, which involved eight effect sizes and four languages (Arabic, Spanish, English, and French). The correlation based on derivation-focused tasks (r = .758) appeared stronger than that based on tasks where there was a mixed focus on inflection and derivation (r = .513) (see Table 5). This seems to suggest a more important role of derivation than inflection in DHH students' reading comprehension, at least for languages where affixation is a salient morphological process. This indication seems particularly interesting, considering that the literature on DHH students' (English) morphological competence and its development has focused largely on inflectional morphology or morphosyntactic aspects. Gaustad and Kelly (2004) found that DHH college students did not differ significantly from reading-matched middle-school students in the knowledge of inflectional morphemes; nevertheless, their knowledge of derivation (and roots) was significantly lower. The present meta-analytic finding, taken together with Gaustad and Kelly's, suggests that English morphological instruction for DHH students would need to give particular, and perhaps sustained, attention to derivation (especially how derivational affixes of varied origins combine with bound roots to generate words) (Gaustad, 2000; Kieffer & Lesaux, 2007).

Limitations of Meta-Analysis, Gaps in the Primary Literature, and Future Directions

Several limitations of the present meta-analysis are noted, and they perhaps also reflect the general gaps in the primary research literature. First, because of the small number of effect sizes that met the inclusion criteria, this meta-analysis did not manage to conduct all moderator analyses of potential interest to explore more widely the effect of various factors on the strength of correlations. For the same reason, moderators occasionally overlapped coincidentally. An example was compounding, which happened to be a focus of studies on Chinese only. With the expansion of primary studies in the future, meta-regression analysis could be conducted to test how different moderators may interact with each other. The literature screening for this meta-analysis showed that not all correlational studies on MA and reading enabled the extraction of any proper correlation. We suggest that all future studies should at least report a full correlation matrix even if the predictive relationships between variables may be the ultimate or more important research goal. In addition, more information could be presented on participants to enable a wider exploration of moderator effects in relation to the heterogeneity in DHH students.

Second, the 14 studies covered 5 languages, but a large majority ($k = 10$) focused on 2, that is English and Chinese. Compared to the literature on hearing students (Lee et al., 2023, for example, covered 17 languages), there is much to be done in terms of the coverage of languages in studying DHH students' reading development.

Third, the included studies showed a very wide age range of participants (the mean age ranging from 5.5 years to 31.8 years). To make the meta-analysis as inclusive as possible of existing correlational studies, we included all age groups, including adult readers or university DHH students. Arguably, however, the literacy experience and stage of reading in adult readers and young elementary school children can show substantial differences; and how these groups of readers understand morphology can also be different. As a result, the present meta-analytic findings, especially those of the moderator analysis on age/reading stage, need to be interpreted with some caution.

Finally, this review only focused on spoken language MA and reading. None of the primary studies searched focused on correlations of sign language MA with either spoken language MA or reading-related abilities. Positive correlations between first (spoken) language MA and second (spoken) language MA and reading abilities, or cross-linguistic transfer of MA, have been widely reported in L2/bilingual readers (see Ke et al., 2021, 2023 for reviews and meta-analyses). How if at all cross-modal, cross-linguistic transfer of skills in sign language morphology, which is unique in terms of its visual modality and simultaneity (Aronoff et al., 2005), may be possible to facilitate reading acquisition remained to be studied in the future. Any positive and significant correlations established of sign language MA with spoken language MA and reading would perhaps provide additional empirical support for common underlying proficiency and bilingual/translanguaging approaches in deaf education.

Conclusions and Implications for Educating DHH Readers

This review and meta-analysis have made at least two contributions to the literature on reading in DHH students. First, it has extended Trussell and Easterbrooks' (2017) systematic review of morphological knowledge with a particular focus on correlation-based studies. Meta-analysis on correlates of reading in DHH students has been rare. Mayberry et al. (2011), to our knowledge, perhaps has remained the only meta-analysis of this kind with a focus on phonological skills and reading. In this respect, the present meta-analysis has filled a notable gap in meta-analyses on DHH students. It of course has also enriched the meta-analytic literature on correlations between MA and reading which has been largely focused on hearing students.

Second, the meta-analytic findings have also generated important insights into the metalinguistic underpinnings of reading acquisition in DHH students. They suggest that MA is an important skill for reading development in DHH students, showing some *qualitative* similarity with other typical literacy learners (Levesque et al., 2021; Nagy et al., 2014; Paul et al., 2013). They perhaps also suggest an important dimension of *quantitative* difference over and beyond what has been reported in the literature. That is, for DHH students, morphology is more predictive of reading (i.e., *quantitatively* stronger in explaining individual differences in reading) in terms of both intra-group reference to phonology (see Mayberry et al., 2011) and inter-group comparison of morphology with hearing students based on existing meta-analytic findings (see Ke et al., 2021; Lee et al., 2023; Ruan et al., 2018). This seems to point to a heightened role, and urgency, of morphological instruction for DHH students.

Pedagogically, on top of the many discussions and research findings on morphological instruction (e.g., Bowers et al., 2010; Carlisle et al., 2010), including those for DHH students (e.g., Gaustad, 2000; Trussell & Easterbrooks, 2015), our meta-analytic findings provide two additional implications. First, while inflection is undeniably important for English-learning DHH students, developmentally, instruction on derivation is much more important and needs to be sustained. Second, morphological instruction needs to go beyond morphographic analysis for (English) word recognition to address the urgent vocabulary and comprehension needs in DHH students through morphological problem-solving where opportunities for semantic construction seem particularly important.

Supplementary Data

Supplementary material is available at *Journal of Deaf Studies and Deaf Education*.

Conflicts of Interest

No conflicts of interest were reported.

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