The association between morphological awareness and reading comprehension in children: A systematic review and meta-analysis

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Abstract

This systematic review and meta-analysis examined the association between morphological awareness and reading comprehension, taking into account critical factors that could affect its strength. Following NIRO guidelines, we included 44 studies involving 63 independent samples, and 126 correlations between morphological awareness and reading comprehension. Overall, we found a significant association between morphological awareness and reading comprehension (r = .565), but also large heterogeneity (81.37%), supporting the need for analysis of potential moderators: age, type of morphologically complex word, characteristics of morphological awareness and reading comprehension tests were examined. We found that type of morphologically complex word was the only significant moderator of this association. In sum, we have demonstrated that morphological awareness influences reading comprehension across a wide age range. Implications for educational practice, as well as recommendations that future studies report more detailed information about participants and measures, are discussed.

Keywords: morphological awareness, reading comprehension, meta-analysis, assessment

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1. Introduction

Morphemes are the smallest units of meaning in language. For example, the word "assessment" means "to make a judgment about something" and is made up of two morphemes: the base "assess" and the affix "-ment"; adding the prefix "re-" to make the word "reassessment" changes its meaning into "to assess something again". Morphological awareness is the "conscious awareness of the morphemic structure of words and someone's ability to reflect on and manipulate that structure" (Carlisle, 1995, p.194). Morphological awareness in children aged 5 to 14 years is strongly associated with different aspects of literacy (e.g., Carlisle, 1995; Deacon & Kirby, 2004; Levesque et al., 2021) and is proposed to support reading comprehension by providing critical information about the meanings of complex words (Rastle, 2019). However, the reported strength of this association differs substantially amongst studies. We conducted a systematic review and meta-analysis of morphological awareness and its association with reading comprehension in children learning to read in English. To understand the basis for differences amongst studies, we explore potential moderators of this association: chronological age, the type of morphologically complex words under investigation, and the characteristics of the measures used to assess both morphological awareness and reading comprehension.

1.1 Morphological awareness

Morphological awareness includes awareness of: the spoken and printed types of morphemes; the meaning that affixes bring to base words (e.g., how *-ed* causes a verb to refer

to the past or *re-* means something occurred again); the manner in which printed affixes connect to base words (e.g., some suffixes require a consonant to be doubled or dropped when attached to a base word in written form); and the relation between base words and their inflected or derived types (e.g., knowing that a variety of words are related because they share the same base, such as act, action, react, and activity) (Apel, 2014).

Morphological awareness can involve different types of morphologically complex word. In English, morphologically complex words are created by three processes: compounding, inflection, and derivation (Carlisle, 2000). Compounding involves combining two or more morphemes to create a new word that has the same grammatical class but a different meaning (e.g., class - classroom). Inflection involves adding affixes to mark grammatical information without changing the grammatical category of the base (e.g., walk - walked). Derivation involves the addition of affixes, which results in a change of meaning, as well as grammatical category (e.g., health - healthy). Morphological awareness and its development have been studied in preschoolers through to adults, but most research has focused on 5- to 12-year-olds, perhaps because studies of morphological awareness typically examine its relationship with reading development (e.g., Carlisle, 1995; Deacon & Kirby, 2004; Nagy et al., 2006). Morphological awareness across the age range, with room for growth after 10 years evident for both inflections and derivations (Anglin, 1993; Carlisle, 2000; Casalis & Luis-Alexandre, 2000; James et al., 2020; Kuo & Anderson, 2006).

1.2 Morphological awareness and reading comprehension

Awareness of different types of morphologically complex words is positively associated with reading comprehension in English-speaking children aged 5 to 14 years (e.g., Carlisle,

1995; Deacon & Kirby, 2004; Nagy et al., 2006). The reported strength of the association is stronger with increasing age in some, but not all, studies (contrast Carlisle, 2000; Deacon & Kirby, 2004, with James et al., 2020). Age range, stimuli, and presentation and response formats differ across studies, and covers awareness of different types of morphologically complex words. Such methodological variation may, in part, account for the range of findings and is addressed in our analyses.

Most studies investigating the association between morphological awareness and reading comprehension in English have focused on inflectional and derivational morphology; few have included compounding (Clark et al., 1986; James et al., 2020). Inflectional morphemes may help comprehension of sentences because they mark the syntactic relations between the words. There is a strong relationship between inflectional morphology and concurrent reading comprehension (e.g., Deacon & Kirby, 2004, $r = .702$; Manolitis et al., 2019, $r = 0.510$), and awareness of inflectional morphology at 7 predicts reading comprehension at 8, 9, and 10 years, after controlling for the influence of phonological awareness and verbal and nonverbal intelligence (Deacon & Kirby, 2004). Extracting a base word from a derived word may have special relevance to reading comprehension when individuals can apply their knowledge of derivational morphology to understand the meaning of unfamiliar derived words (Carlisle, 2000). Awareness of derivations is associated with reading comprehension between 8 and 12 years after controlling for the influence of variables such as vocabulary and word reading (Gilbert et al., 2014; Kieffer & Box, 2013; Metsala et al., 2019).

Despite this theoretical separability, the majority of studies have examined awareness of

inflection and derivation together as a single construct, rather than independently (e.g., Apel & Henbest, 2016; Levesque et al., 2017; Tong et al., 2013). A notable exception is a one-year longitudinal study of Greek beginner readers (Manolitsiset al., 2017), which found that morphological awareness of inflection and derivation at 5 and 6 years and of compounding at 6 years accounted for unique variance in reading comprehension at 6 and 7 years. In a cross-sectional study, James et al. (2020) found that separate measures of morphological awareness of compounding, inflection, and derivation were related to concurrent reading comprehension in three age groups (6-8 years, 9-11 years, and 12-13 years) after controlling for non-verbal reasoning, vocabulary, phonological awareness, and word reading. In summary, the type of morphologically complex words used to assess morphological awareness when investigating its association with reading comprehension varies, and it is unclear whether one type (inflection, derivation or compounding) has a stronger influence than another.

As noted, there may be different developmental patterns for the three different types of morphology we consider here (compounding, inflection, derivation), but few empirical studies that have contrasted the association between these three types and reading comprehension. One exception is Kirby et al. (2012) who proposed that the predictive effect of awareness of inflectional morphology on reading comprehension might peak early, whilst awareness of derivational morphology might continue to predict reading for longer as children's knowledge about derivational morphological continues to develop. However, there is no large scale review, to date, that has examined this proposal. We addressed this gap by collating the results of studies that have explored the relationship between morphological awareness and reading comprehension for different types of morphological complex words in

different age groups.

1.3 Morphological awareness tests

A variety of tests have been used to measure morphological awareness and we consider the influence of pertinent task characteristics in our analyses. In the Word Analogy Task (Nunes et al., 1997a,b), participants are presented with a pair of morphologically related words (e.g., work: worker) followed by the first word of a second pair (teach: __), and asked to complete the pattern by providing the second word in the second pair to match the model of the first (correct response: teacher). The Test of Morphological Structure (Carlisle, 2000) involves completion of a sentence frame (e.g., Farm. My uncle is a ___. [farmer]). In the Suffix Choice Task, (Nagy et al., 2003) participants choose which of four words best fits a context sentence (e.g., “Did you hear the _____?”) based on its inflectional or derivational suffix (e.g., directs, directions, directing, or directed). Although the Word Analogy Task and Test of Morphological Structure differ in format, the participant is presented with the base form and required to produce a derivation or inflection in each; thus, these two tests assess awareness of the relation of base words to their inflected and derived types. In contrast, the Suffix Choice Task assesses awareness of the meaning of affixes and the change in grammatical class they bring to base words. We examined whether such differences influence task performance and its relation with reading comprehension.

In addition, response format is proposed to affect test difficulty and influence the strength of the association between morphological awareness and reading comprehension (Apel & Thomas-Tate, 2009; Apel et al., 2012; Carlisle, 2000). Specifically, production tasks that require children to generate a base word and its derived form might be more difficult

than tasks that require them to judge the relatedness between two given forms (Apel & Thomas-Tate, 2009). The modality of the response might also affect this association because written output is more heavily dependent on vocabulary and spelling knowledge (Stark, 2011), both related to reading comprehension. The potential influence of output modality on the strength of the association between morphological awareness and reading comprehension needs to be examined because the written response format has been used more frequently with older students, which may impact on reported age differences in the relation between morphological awareness and reading comprehension. Such knowledge is critical to inform both our theoretical understanding of the construct of morphological awareness and to develop sensitive and robust measures of this skill.

Research to date confirms the need to also consider the influence of task presentation. Aural input might help readers to decompose morphologically complex words, especially low frequency words, through its association with lexical prosody; correct pronunciation will support the recognition of morphemes and their lexical representations during morphological analysis (Carlisle, 2003; Chan et al., 2020). Carlisle (2000) presented the Test of Morphological Structure aurally and found a stronger relationship between morphological awareness and reading comprehension than did Stark (2011) who presented the stimuli in written form. Mahony et al. (2000) assessed 8- to 12-year-olds with a written version and a combined version (oral and written) version of the Morphological Relatedness Test. They found that test scores for the younger children were higher with oral and written presentation compared with only written presentation, but this advantage decreased with increasing age.

Not all measures of morphological awareness use real words; some include pseudoword

stimuli (Apel & Henbest, 2016). When real word stimuli are used, one cannot determine whether explicit application of morphological rules or prior vocabulary knowledge drives performance because participants may correctly perform the test by reference to their vocabulary knowledge. When pseudowords are used, readers must utilize their knowledge of morphological rules because, by definition, there is no meaning attributed to a pseudoword. Tests using pseudowords are more difficult than those using real words for students with reading difficulties (Siegel, 2008, see also Tighe & Schatschneider, 2015).

1.4 Reading comprehension tests

Just as there are many different measures of morphological awareness, different reading comprehension tests have different formats that are not necessarily interchangeable (Keenan et al., 2008). Performance on reading comprehension measures that use cloze and picture-matching response formats are more strongly related to word reading than listening comprehension; in contrast, performance on measures that use an open-question format are more strongly related to listening comprehension (Keenan et al., 2008). These striking differences highlight the need to take into account the format of the reading comprehension test when examining the strength of the association between reading comprehension and morphological awareness. In addition, the type of comprehension processing involved may make a difference, because good and poor comprehenders differ more in their ability to answer questions tapping inferable information than explicitly stated information (Cain & Oakhill, 1999). These differentiating features of reading comprehension assessments (test format and depth of processing required by response) were addressed in our systematic review and meta-analysis.

1.5 Prior reviews and meta-analyses

Several meta-analyses have examined the association between morphological awareness and reading ability, to date (Bratlie et al., 2022; Goodwin & Ahn, 2010, 2013; Ke et al., 2020; Lee, 2011; Ruan et al., 2018), but only two are relevant to our aims. Ruan et al.'s (2018) found that, for English participants, correlations between morphological awareness and reading comprehension were significant even after controlling for the influence of phonological awareness. However, they did not test for the effects of age, type of morphologically complex word, nor the format of the morphological awareness and reading comprehension tests. Bratlie et al. (2022) found that the size of differences in morphological knowledge between groups from language minority and language majority backgrounds was positively associated with the size of group differences in vocabulary, syntactic knowledge reading comprehension. However, their meta-analysis did not directly address critical issues for our work including the association between morphological awareness and reading comprehension, and it did not focus on English.

1.6 The aims of the current study

We address several outstanding questions about the association between morphological awareness and reading comprehension focusing on research including beginner readers through to late adolescents learning to read in English as a first language. Our over-arching aim is to determine the strength of the association with reading comprehension during the school years. Our review highlights a range of developmental and measurement factors as potential critical moderators in this relationship, yet previous research has not systematically studied their influence. This severely limits our theoretical understanding of the relationship

between morphological awareness and reading comprehension and its role in reading development. In a pre-registered set of analyses, we address the following questions:

1) Does the age of participants affect the relationship between morphological awareness and reading comprehension? Based on previous studies, we predicted a stronger relationship with increasing age (Carlisle, 2000; Deacon & Kirby, 2004).

2) Do the types of morphologically complex word affect the relationship between morphological awareness and reading comprehension? Based on previous work (e.g., Kirby et al. 2012, Tong et al. 2014), we expected the strength of the relationship between morphological awareness and reading comprehension to differ by word type, in particular we predicted a stronger association between awareness of derivational morphology and reading comprehension than between inflectional morphology and reading comprehension.

3) Do characteristics of morphological awareness tests affect the relationship between morphological awareness and reading comprehension? We explored if any characteristics of measures of morphological awareness influence the strength of the association between morphological awareness and reading comprehension. Specifically, we examined: (a) input modality of the stimuli; (b) presence of contextual support for the morphological awareness test; (c) nature of the word stimuli; (d) output modality of the morphological awareness test; (e) nature of the response of the morphological awareness test, and (f) aspect of awareness.

4) Do characteristics of reading comprehension tests affect the strength of the association between morphological awareness and reading comprehension? Specifically, we sought to determine the influence of the following aspects of the reading comprehension measure: (a) process of interpretation; (b) passage length; (c) response format; and (d)

response task.

2. Methods

This study was designed and preregistered according to the NIRO guidelines (Topor et al., 2020). The preregistration can be found on OSF. Full details on all aspects of the methods can be found in the relevant sections of part B of the NIRO guideline in the supplementary material A and on OSF.

2.1 Data Collection, Inclusion Criteria, and Inclusion Reliability

Figure 1 summarizes the data collection and inclusion process. Relevant studies were identified through a search in the PsycInfo, ERIC, PubMed, PsycArticle, ProQuest Dissertation Theses Global, and Linguistics and Language Behavior Abstract (LLBA) databases using “morph*” and “read*” as search terms. We also emailed the Society for the Scientific Study of Reading (SSSR) for unpublished data. More information can be found in sections B7, B8, and B9 of the NIRO protocol in the supplementary material A. We included a range of publications (peer-reviewed journals, book chapters, PhD theses) to guard against “publication bias” (Glass et al., 1981; Macaskill et al., 2001; Rosenthal, 1995). The search yield 10,668 records. After removing duplicate papers, 8,198 records were closely reviewed using the specific criteria shown in Figure 1. For longitudinal studies and intervention studies, only data of the pre-test were included. In total, 44 studies were included in our analysis.

The first author screened all records. To check the accuracy and reliability of the coding rubric, 10% (n = 820) of the records were also screened by two trained volunteers. This is a comparable proportion to that used in another meta-analysis by García and Cain (2014), and

used for all inter-rater reliability checks in this paper. The inter-rater reliability indicated substantial agreement (Kappa = 0.755, 95% CI [.713, .797]) (Landis & Koch, 1977). The full text of 10% (n = 100) of the records were also screened by two volunteers. The inter-rater reliability indicated almost perfect agreement (Kappa = 0.950, 95% CI [.833, 1.000]) (Landis & Koch, 1977). More information can be found in section B14 of the supplementary material A.

2.2 Data extraction

The main aim was to assess the association between morphological awareness and reading comprehension. We treated reading comprehension as the dependent variable and morphological awareness as the independent variable. The moderator variables were: participant age; type of morphological complex words examined; the characteristics of the morphological awareness tests, and the characteristics of the reading comprehension test. More information can be found in section B16 of the supplementary material A.

2.2.1 Moderator variables

There were two moderator variables of primary interest: (1) Age. The mean ages of the children in the studies that met the inclusion criteria ranged from 7 to 16 years old. Mean chronological age in months was coded; (2) The type of morphologically complex word was coded as follows: compounding, inflection, derivation, inflection and derivation, and all (i.e., compounding, inflection and derivation).

2.2.2 The characteristics of the morphological awareness and reading comprehension tests

Six characteristics of the morphological awareness tasks and four characteristics of the

reading comprehension tests were considered (Table 1). We included 44 studies in the stages of data extraction. The first author coded all 44 included papers. To check the accuracy and reliability of the coding rubric, 10% (n = 4) of the records were also coded by two volunteers. The inter-rater reliability indicated almost perfect agreement (Kappa = 0.923, 95% CI [.818, .1.000]) (Landis & Koch, 1977). See Table 2 for the inter-rater reliabilities of variables, and see section B18 of the supplementary material A for more detail.

2.3 Missing data

Not all studies provided sufficient information for the variables of interest. In such cases, we contacted authors by email to obtain the missing information. In some cases, the overall correlation between morphological awareness and reading comprehension was provided, but not the correlations between separate tests of morphological awareness and reading comprehension. For these cases, the study was included in the general analysis but excluded from the moderator analysis. Where mean chronological age was missing but grade level was available, we estimated mean chronological age based on the median age of the typical age range for the reported grade. If other moderator variables were missing and could not be provided, the study was excluded from the moderator analysis for which data were missing, but included in all moderator analyses for which data were provided.

2.4 Risk of bias assessment

An adapted version of the Joanna Briggs Institute Checklist for Analytical Cross-Sectional Studies (Moola et al., 2017) was used to assess the risk of bias and the methodological quality (see section B19 of the supplementary material A for detail). Most of the included studies (n = 31) were considered as low risk, whilst 13 were considered high

risk. The first author coded all 44 included papers. The assessment of 10% (n = 4) of the records were also coded by two volunteers. Inter-rater reliability indicated strong agreement (Kappa = 0.899, 95% CI [.824, .974]) (Landis & Koch, 1977). See Table 3 for the inter-rater reliabilities of checkpoints of risk of bias, and see section B20 of the supplementary material A for detail.

2.5 Meta-analytic procedures

All data analyses were conducted in R studio (Version 1.4.1103; R Core Team, 2020). There were four main steps. First, we transformed correlation coefficients to Fisher's Z scores and calculated the corresponding sample variance. Second, as many data were dependent and avoiding the loss of data and statistical power, we corrected dependency in data, rather than aggregating several effect sizes into one composite effect size (Fisher & Tipton, 2015). To take dependency among data into account, multilevel modeling can be used to account for clustering based on a correlational matrix (Gunnerud et al., 2020); or one can use robust variance estimation (Fisher & Tipton, 2015). Multilevel modelling requires data from within-study correlation matrices, but this information was lacking from 12 out of 44 papers. The robust variance estimation approach does not require information about within-study covariance, but instead is based on robust estimate of heteroscedasticity and clustered SEs in the general linear model (Liang & Zeger, 1986; White, 1980). Heteroscedasticity estimates the change in the spread of residuals over the range of observed values in a systematic way, and clusters standard errors in the general linear model (Liang & Zeger, 1986; White, 1980). Robust variance estimation is now recommended for meta-analyses where data dependencies occur (Hedges et al., 2010; Tanner-Smith et al., 2016; Tanner-Smith & Tipton, 2014).

We used RobuMeta for R (Fisher & Tipton, 2015) to implement robust variance estimation using a correlated effects working model (equivalent to a random effects model) and small-sample adjustments (Tipton & Pustejovsky, 2015). Where more than one measure of morphological awareness was reported for the same sample, we used a correlational weights approach to mitigate for this dependency. An alternative to the correlated effects working model is hierarchical model weighting (Fisher & Tipton, 2015). This can be used when there is a second level of nesting, for example when observed effect size estimates are nested inside studies within clusters, or when studies from the same research group share something in common with each other (such as the same paradigm). In addition to the correlated weights analysis, we report the primary results with hierarchical weights and note where findings differ. Finally, we conducted a sensitivity analysis to ensure that the results were robust across several levels of correlations.

Third, moderator effects were tested using regression models in the RobuMeta package, when at least five datapoints were included in a moderator analysis or category level (Bakermans-Kranenburg et al., 2003). The multiple-contrast hypothesis tests were conducted using the Wald-test function using the clubSandwich package in R (Pustejovsky, 2017). Fourth, publication bias was examined with a funnel plot and rank correlation test of aggregated correlations using MAc in R (Hunter & Schmidt, 2004).

3. Results

The main analysis included 44 studies involving 63 independent samples, 13,790 participants, and 126 correlations between morphological awareness and reading comprehension. The data were dependent because many studies reported more than one effect

size, so robust variance estimation (RVE) was used (Gunnerud et al., 2020) to adjust statistically for dependency. For each RVE, we report the number of effect sizes (*k*), clusters (*m*), and degrees of freedom (*df*).

3.1 The relationship between morphological awareness and reading comprehension

The large and significant mean effect size indicates a positive relationship between morphological awareness and reading comprehension: $r = .565$, 95% CI [.534, .595], $k = 126$, $m = 63$, $df = 58.60$, $p < .001$. The true heterogeneity between studies was substantial, $I^2 = 81.37\%$, $\tau^2 = .021$. A sensitivity analysis with a correlation level of outcomes set to the range 0 – 1 showed no differences in effect size or standard error (SE). There were no changes in τ^2 from the sensitivity analysis ($\tau^2 = .021$). An analysis performed via hierarchical weights and a small-sample correction confirmed these results ($r = .531$, 95% CI [.498, 562], $k = 126$, $m = 63$, $df = 30.30$, $p < .001$), and showed within- and between-study variation in true effect sizes ($\tau^2 = .010$, $\Omega^2 = .009$). In sum, there was a large, positive association between morphological awareness and reading comprehension. The true heterogeneity indicated substantial variability in size, supporting the need to examine the effects of predicted moderators of this association.

3.2 Moderator analyses

Studies for which we were unable to obtain the relevant correlations, were excluded from one or more moderator analyses. Overall, the moderator analyses included 37 studies involving 51 independent samples, 11,287 participants, and 114 correlations between morphological awareness and reading comprehension tests. The large and significant mean effect size reported above for the main analysis was also found when considering only the

studies included in the moderator analyses: r = .543, 95% CI [.511, .573], k = 114, m = 51, df = 46.80, p < .001. Similarly, the true heterogeneity between studies remained substantial, I^2 = 80.12%, τ^2 = .019. A sensitivity analysis with a correlation level of outcomes set to the range 0 – 1 showed no differences in effect size or SE. There were no changes in τ^2 from the sensitivity analysis (τ^2 = .019). The analysis performed with hierarchical weights and a small-sample correction confirmed the large and significant association between morphological awareness and reading comprehension (r = .517, 95% CI [.483, 549], k = 114, m = 51, df = 25.30, p < .001), and showed within- and between-study variation in true effect sizes (τ^2 = .008, Ω^2 = .009). One continuous moderator (chronological age) and three categorical moderators (type of morphologically complex word, characteristics of morphological awareness and reading comprehension tests, respectively) were examined. For categorical moderators, the contrast was tested only where there were 4 or more datapoints (Bakermans-Kranenburg et al., 2003). For transparency, all results are provided in Tables 2- 4.

3.2.1 The moderator effects of age and types of morphologically complex words

The moderator effects of mean age and type of morphologically complex word were examined first, followed by the interaction between them. Although the mean ages of the children in these studies ranged from 6 to 16 years, most studies focused on 8 to 12 years. Seven independent samples involved participants in the initial stages of reading (6 - 8 years), 34 in the intermediate stages of reading (8 - 12 years) and 10 on older participants. Contrary to predictions, chronological age did not have a significant effect on the association between morphological awareness and reading comprehension, r = -.002, 95% CI [-.004, .001], k = 114, m = 51, df = 16.90, p = .162.

There were 32 correlations from 9 studies that did not report the chronological age of participants. Of the 93 data points examining students under 12 years, 22.58% were our estimates of mean age; of the 22 data points examining students older than 12 years, 50% of these were estimates (Figure 2). Thus, the effect of missing data had a bigger influence for participants older than 12 years. To address this issue, we analyzed the data of only those studies that provided mean chronological age. Age had a small effect on the association between morphological awareness and reading comprehension: the correlation decreased with age, r = -.003, 95% CI [-.005, -.001], k = 82, m = 34, df = 10.60, p = .002. The difference between the analysis using estimated age and the one using only studies with reported age is very small, and each revealed a very small effect size (estimated age: z = -0.002, 95 % CI [-0.004, 0.001], τ^2 = 0.02; reported age: z = -0.003, 95 % CI [-0.005, -0.001], τ^2 = 0.01). The two analyses suggest that the effect of age on the relationship between morphological awareness and reading comprehension is close to zero.

The type of morphologically complex word had a significant effect on the association between morphological awareness and reading comprehension, k = 112, m = 51, df = 8.25, p = .016, and the heterogeneity was still large, I^2 = 73.1% (Table 6). Morphological awareness tests that contained both inflected words and derivational words had the strongest relationship with reading comprehension, whilst those with compounding words had the weakest. Of note, the number of studies across the four categories was not equal: 72 studies tested derivational morphology, but only 6 studies tested compounding and 8 tested inflectional morphology. Pairwise contrasts demonstrated a significantly stronger association when measures included both inflectional and derivational morphology relative to those involving just derivational

items, $F = 15.70$, $df = 37.20$, $p < .001$ (Table 6). The interaction between these two moderators (age and type of morphologically complex word) was not significant, $F = 1.80$, $df = 3.50$, $p = .291$ (Table 6).

3.2.2 The moderator effects of the characteristics of morphological awareness tests and reading comprehension tests

For the moderator analyses that examined the influence of different characteristics of the measures used to assess morphological awareness and reading comprehension, the effect of one moderator at a time was considered in robust variance estimation. As contrasts were tested only where there were four or more datapoints (Bakermans-Kranenburg et al., 2003), some subgroups were excluded: "all types" from morphologically complex words ($k = 2$), "familiarity rating" from nature of response ($k = 1$), and "selecting a word in a cloze task" from the response task category ($k = 1$). Additionally, in the category of level of understanding (for reading comprehension tests), there were insufficient datapoints to conduct the analysis (inferential $k = 2$, both $k = 101$).

The characteristics of morphological awareness tests did not have significant effects on the association between morphological awareness and reading comprehension. The three categories for the nature of the input modality (visual, aural, or both) each yielded similar effect sizes but, after this moderator analysis, the heterogeneity was still large (Table 5). A similar pattern was found when examining the moderators for context, word stimuli, output modality, nature of response, and aspect of awareness. Three findings are noteworthy. First, relatively few studies included in our analyses used pseudoword stimuli: Just 13 in comparison to 100 that used real words. Second, written input and output were used more

often with participants older than 10 years, whilst oral input and output were used more among participants younger than 10 years (Figures 3, 4). Third, four categories for aspects of awareness were considered. Despite differences in the size of the effects between these different categories (ranging from .421 to .657), the effect of this moderator did not reach significance (k = 107, m = 51, df = 5.03, p = .068). However, there were few studies (N=7) that included measures of awareness of the meaning of affixes and the alterations in meaning they bring to base words, the aspect of awareness with the largest effect size (r = .657). The imbalanced data may have affected the ability to detect their influence.

The systematic review found that research in this field has used a variety of reading comprehension assessments, with both short and long passage lengths, different response tasks (open questions and cloze), as well as different response formats (production and selection from multiple options) to assess comprehension. There were a sufficient and sizeable number of studies for analysis. None of these moderators were significant, but the heterogeneity was still large (Table 4). For the reading comprehension test format, there was too much missing data under the level of understanding, and the distribution of two categories of level of understanding was too imbalanced to conduct the analysis (inferential k = 2, both k = 101).

3.3 Publication bias

A funnel plot (Figure 5) showed that studies were distributed mostly symmetrically around the mean effect size. The rank correlation test was not significant (τ = -.130, p = .133). Together, these do not indicate significant publication bias, although we note that possibility.

4. Discussion

This is the first systematic review and meta-analysis of the association between morphological awareness and reading comprehension in children learning to read in English as a first language. A strong positive and significant association was found: children who performed better on tests of morphological awareness also performed better on measures of reading comprehension. This result is consistent with the body of educational and psychological research that speaks to the importance of good morphological awareness for successful reading comprehension (e.g., James et al., 2020; Levesque et al., 2019; Tong et al., 2014). At the same time, there was substantial heterogeneity in the findings, supporting the rationale to examine potential reader and measurement characteristics as moderators of the strength of this association. These are discussed in turn, along with the implications for educational practice and future research.

4.1 The moderator effect of age

The age range in the studies included in our analysis was 6 to 16 years. In contrast with several influential studies (Carlisle, 2000; Deacon & Kirby, 2004), we did not find an age-related increase in the strength of the association between morphological awareness and reading comprehension. Age was treated as a continuous variable in our analyses. A posthoc analysis in which age was split into two groups (younger than 12 years vs 12 years and older) did not reveal any significant associations between variables for younger and older children. Thus, when considering the literature as a whole, our meta-analytic approach provides evidence that morphological awareness is important for reading comprehension across a long period of reading development.

We note the imbalance in age groups studied previously and how this limits a precise

understanding of the relationship between morphological awareness and reading comprehension. Few studies include readers under 8 years of age, as noted by Levesque et al. (2021), yet morphology may have a significant influence in early reading development supporting the transition from beginner reader to expert. Future studies should include children across a broader age range, especially children younger than 6 years at the very beginning stages of reading development. Although reading comprehension is strongly influenced by word reading ability in young children (e.g., LARRC, 2015), a longitudinal study may be helpful to determine when morphological awareness starts to influence reading comprehension and if it has a significant influence across the entire developmental range. Such work is necessary to build a more comprehensive account of the relationship between morphological awareness and reading comprehension across reading development and develop clearer guidance for morphological instruction.

Many studies reported only school grade (not chronological age), particularly those with students older than 12 (Figure 2), resulting in missing data for adolescent readers. In addition, some studies reported a single correlation for children covering more than one school year (or grade). Our analyses with both reported and estimated chronological age were comparable. However, the lack of reported age compromised our desire to study also the influence of years of schooling. Even amongst English-speaking countries, age of school entry and, therefore, the start of formal literacy instruction differs and this is potentially an important moderator: In the study of the relationship between word reading and reading comprehension, different patterns of association are found when contrasting chronological age and school grade (Florit & Cain, 2011). We strongly recommend that developmental research on

language and literacy reports both the mean and range of chronological age, as well as years of literacy instruction, to enable a more precise estimate of the impact of development and educational instruction on the critical associations between language and literacy skills.

4.2 The moderator effect of type of morphologically complex words

Different types of morphologically complex words used in the assessment of morphological awareness were examined: compounding, inflection, derivation, and tests assessing both inflection and derivation. The systematic review revealed that most studies focused on derivation (64.29% of datapoints), few included measures of compounding, whilst it was relatively common for a measure to include both derivation and inflection (23.21% of datapoints). The moderator effect of type of morphologically complex word was significant. However, pairwise comparisons determined a significant difference only between tests of morphological awareness that included *both* inflection and derivation versus derivation alone, which does not support earlier theories about the difference between derivation and inflection and the reasons for their relation to reading (e.g., Kirby et al., 2012; Tong et al., 2014). One possible reason for this finding, is that too few studies included measures of only inflectional morphology awareness, so we could not examine its unique influence. However, the significant difference between the strength of association between measures of reading comprehension and both inflectional and derivational morphological awareness versus derivational alone suggests the need for studies that directly investigate the influence of different types of morphology in relation to reading.

An additional limitation of this specific moderator analysis was that the number of data points included in the different categories was highly imbalanced. The vast majority of

studies measured derivational morphology, which is a broader measure than compounding and also inflectional morphology. There are likely different developmental trajectories of the awareness of different types of morphologically complex word (Tyler & Nagy, 1989, see also James et al., 2020). We did not find significant interactions between different types of morphologically complex word and age. As for other moderator analysis, the imbalance in the number of studies that measured different types of morphologically complex words, missing data for chronological age, and the narrow age range included in most studies may all have limited the sensitivity of our analyses. Thus, the interaction between age and types of morphologically complex words should be a focus of future research.

4.3 The moderator effects of characteristics of morphological awareness tests

Despite theorized relations between characteristics of the measures used to assess morphological awareness and their association with reading comprehension, we did not find any significant effects. Again, as revealed by our systematic review, the number of correlations for some critical characteristics was imbalanced. Notably there were very few correlations involving pseudoword stimuli, despite the concern about the impact of vocabulary knowledge on real-word measures of morphological awareness, which makes it hard to disentangle the unique relationships between vocabulary, morphological awareness, and reading comprehension (see Tighe & Schatschneider, 2015, on this point). Given the significant theoretical debate about these potential moderators (Apel & Henbest, 2016; Bratlie et al., 2022; Kieffer & Lesaux, 2012), future research should examine their association with reading comprehension.

We found a numerically stronger relation between reading comprehension and measures

of morphological awareness tests that used aural presentation of stimuli compared with visual presentation, in line with previous research (Carlisle, 2000 vs Stark, 2011). We also found a numerically stronger association when the morphological awareness tests required an oral output (response) compared to written output. However, neither moderator effect was significant.

The lexical prosody (or the placement of primary stress when speaking) provided by aural input may aid performance by providing the critical scaffold to decompose morphologically complex words. This could be especially helpful for low frequency words, thereby artificially inflating the performance on task and influencing its relation with other literacy variables (such as reading comprehension). In contrast, written tasks rely on orthographic knowledge and decoding skills (Bratlie et al., 2022). Our meta-analysis cannot speak directly to this point and additional research is required.

Related to this point, for both input and output, a spoken format was more common for younger children and a written format more common in studies with children older than 10 years (Figures 3, 4). These differences may arise because written input and output enable group-administered tasks that older children can work through independently, whereas the reading and spelling requirements may be considered too challenging for reliable measurement for younger children. Thus, differences in presentation and response formats by age may be a confounding factor influencing the association between morphological awareness and reading comprehension.

Morphological awareness tests that used a multiple-choice response format had a numerically larger, but not significant, correlation with reading comprehension than those

requiring word production. Production tasks that require children to generate a base word and its derived form might be considered more difficult than tasks requiring them to judge the relatedness between two given forms (Apel & Thomas-Tate, 2009), and are also more heavily reliant on spelling and word reading skills than are judgement tasks. This difference supports the idea that judgement tasks and production tasks may have different strengths of association with reading comprehension (Apel & Thomas-Tate, 2009; Apel et al., 2012; Carlisle, 2000), a proposal that needs to be tested in future research.

There were larger correlations between reading comprehension and tests that assessed awareness of the morphemic units in words relative to those that assessed awareness of the meanings of affixes and the alterations in meaning that they bring to base words. The former maps on to Goodwin et al.'s (2021) category of morphological-semantic knowledge, which refers to the ability to infer the meaning of morphological complex words based on the semantic information in morphemes; the latter maps on to Goodwin's skill of morphological-syntactic knowledge. Our data-driven bottom-up approach differs from Goodwin et al.'s (2021) categorization, but provides broadly converging findings that morphological knowledge is multidimensional and that different assessments of morphological skills tap different processes and aspects of knowledge, which may influence the strength of the association with reading comprehension. For a more comprehensive understanding of the relationship between language, processing skills, and reading comprehension, future studies should examine multiple aspects of morphological awareness and its measurement.

It is important to consider our findings in relation to models of reading comprehension. According to the Reading Systems Framework (Perfetti & Stafura, 2014), word identification

occurs when the orthographic units in the written text activate their associated phonological units through knowledge of orthography-phonology mappings. This orthographic system is connected to the linguistic system, which includes phonology, morphology and syntax. Together, these systems support access to the lexicon enabling retrieval of the meaning, morphology and syntax of words. Understanding the individual words in a text is fundamental for text comprehension and the importance of morphology in this process was recognized in Perfetti and Stafura's (2017) updated framework, in which the orthographic units map to morphology in addition to phonology in the orthographic system. Related to this, Levesque et al. (2021) have proposed that metalinguistic awareness of morphology (and also phonology and syntax) should be represented within such models, and they adapted the Reading Systems Framework to reflect this view. In their Morphological Pathways Framework, morphological awareness supports word comprehension through the morphological analysis pathway, which links the orthographic and linguistic systems directly to morphological, semantic, and syntactic representations in the lexicon. Word decoding is supported by morphological awareness via a pathway that links knowledge of the orthographic system with word identification processes (orthographic-phonological unit mapping and the lexicon).

Such frameworks explicate how characteristics of morphological awareness tests may influence the strength of the association between morphological awareness and reading comprehension. Taking input modality as an example, these frameworks included a direct route from aural input to morphological units, whilst visual input additionally involves orthography to morphology mappings. Taking "misheard" as an example, for spoken

presentation participants will hear the morphemes "*mis+heard*" directly and understand the word more easily; visual presentation, allows for incorrect decomposition into "*mish+eard*" (Levesque et al., 2017). These differences might explain the stronger correlations we found between aurally presented morphological awareness tests and reading comprehension than visually presented tests. In addition, awareness of the meaning of affixes and the alterations in grammatical class they bring to base words may tap more strongly into morphological-syntactic knowledge, whilst awareness of the meaning of affixes and the alterations in meaning they bring to base words may be a stronger measure of morphological-semantic knowledge (Goodwin et al., 2021). Therefore, the aspects of awareness examined here may map onto different processes involved in reading comprehension and, potentially, different strengths of association. Future studies could test these frameworks longitudinally to further expand our understanding of the role of morphology in reading comprehension and its development.

4.4 The moderator effects of characteristics of reading comprehension tests

Finally, it had been demonstrated that reading comprehension tests are not necessarily interchangeable; different tests have different formats and show different strengths of relation with each other and also word decoding and listening comprehension (Garcia & Cain, 2014; Keenan et al., 2008). However, we did not find an effect of any test features on the strength of the reading comprehension and morphological awareness association. The distribution of most characteristics was balanced suggesting that our finding is robust and that the nature of the reading comprehension assessment has little impact on its association with an individual's morphological awareness. However, we were not able to investigate all features of interest,

for example level of understanding, because of insufficient detail in the method sections of published research.

4.5 Limitations and future directions

This study systematically and comprehensively investigated the relationship between morphological awareness and reading comprehension. By taking a systematic approach, we have identified several limitations, as well as recommendations for future research. In addition to the limitations of missing data and the imbalanced distribution of datapoints across categories, we also note a limitation in the description of both participants and assessments. First, some studies lacked detail about languages spoken and not all reported demographics other than age and gender. Thus, some of the studies included here may not meet a strict definition of English speakers. In addition, the validity and reliability of the morphological awareness tests were not always reported. We strongly recommend that researchers report detailed demographic information, including language background, as well as information about test development and psychometrics to aid interpretation and guide measurement selection.

In relation to the scope of future research in this area, we have identified the need for studies of students younger than 6 years and older than 12 years and a consideration of different types of morphologically complex words. Such knowledge is required to provide clearer guidance for educators, such as when to focus on morphology in classroom instruction, and the types of morphology that should be included for different age groups. In addition, although our study supports the association between morphological awareness and reading comprehension, we were not able to control for other metalinguistic awareness or

language variables, such as phonological awareness and vocabulary, which are both associated with morphological awareness and reading comprehension. However, because of the variety of research questions, there would be much fewer studies included if everything was controlled. Such a focus would have limited our meta-analysis to a small group of studies conducted by a restricted group of researchers. Also, our research questions were limited to the concurrent association between morphological awareness and reading comprehension, so did not address issues of causality. We recommend that future systematic review and meta-analysis examine issues of causality by including longitudinal studies, which can shed light on the direction of the causality, and intervention studies, which can shed light on causality by determining if morphological awareness training strengthens the relationship between morphology and reading comprehension. Finally, we recommend that future research examines the characteristics of morphological awareness tests. Morphological awareness is multidimensional and tests may vary in their reliance on different language knowledge and processes.

Our study also has some implications for education practice. First, the important role of morphological awareness in reading comprehension supports calls for instruction in morphology for students to improve reading comprehension (Bowers et al., 2010). Of course, reading comprehension may also support morphological awareness and reciprocal relations between reading comprehension and vocabulary, highly related to morphological knowledge, are well established (e.g., Verhoeven et al., 2011). It has been shown that children with reading comprehension difficulties do more poorly than peers on assessments of morphological awareness (Tong et al., 2011). Thus, a focus on early instruction in

morphology, as well as targeted support for poor readers, has the potential to raise reading comprehension performance. We note that the association between reading comprehension and measures of morphological awareness that used either nonword or real word stimuli were both significant and comparable. Thus, until further evidence is available, educators should assume that measures of morphological knowledge that use real words tap more than simply vocabulary knowledge.

5. Conclusion

In summary, our comprehensive and systematic review demonstrate a significant and stable association between morphological awareness and reading comprehension across a wide period of reading development indicating that instruction in morphology may benefit even beginning readers. This association was affected by the types of morphologically complex words included in an assessment. Other potential moderators, such as age, and characteristics of assessments, did not have a significant effect on the association between these two variables. We highly recommend that future studies report more detailed information about participants and measures to provide the critical information needed to understand better the mechanism(s) by which morphological awareness influences reading comprehension, as well as provide clearer guidance for morphological instruction.

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Table 1
The characteristics of morphological awareness test and reading comprehension test

Characteristics	Categories
Morphological awareness	
Input modality	Oral
	Written
	Both
Context of word stimulus	A single word presented alone
	A pair of words
	A single sentence
	One uncompleted sentence
	One uncompleted sentence with one single word
	A pair of sentences plus one single sentence
Word stimuli	Real word
	Pseudoword
	Both
Output modality	Oral
	Written
Nature of response	Producing a word
	Producing a sentence
	Yes/no decision
	Multiple-choice
	Read/repeat
	Familiarity rating
Aspect of awareness	Awareness of the relation of base words to their inflected and derived types
	Awareness of the meaning of affixes and the alterations in meaning they bring to base words
	Awareness of the meaning of affixes and the alterations in grammatical class they bring to basewords
	Awareness of morphemic units in words
Reading comprehension	
Level of understanding	Inferential
	Literal
	Both
Passage length	Short (less than three sentences)
	Long
Response format	Cloze
	Question
Response task	Producing an idea in response to an open-ended question
	Selecting an idea in response to a question prompt
	Producing a word in a cloze task
	Selecting a word in a cloze task

Table 2

The inter-rater reliabilities of variables

Characteristics	Inter-rater reliability	Kappa
Age	Perfect agreement	1
Types of morphological complex words	Perfect agreement	1
Morphological awareness		
Input modality	Perfect agreement	1
Context of word stimulus	Substantial agreement	0.625
Word stimuli	Perfect agreement	1
Output modality	Perfect agreement	1
Nature of response	Substantial agreement	0.657
Aspect of awareness	Substantial agreement	0.657
Reading comprehension		
Level of understanding	Substantial agreement	0.625
Passage length	Perfect agreement	1
Response format	Substantial agreement	0.657
Response task	Substantial agreement	0.625

Table 3

The inter-rater reliabilities of checkpoints of risk of bias

Characteristics	Inter-rater reliability	Kappa
Were the criteria for inclusion in the sample clearly defined?	Almost perfect agreement	0.944
Were the study subjects and the setting described in detail?	Almost perfect agreement	0.865
Was the exposure measured in a valid and reliable way?	Almost perfect agreement	0.909
Were the outcomes measured in a valid and reliable way?	Almost perfect agreement	0.956
Was appropriate statistical analysis used?	Almost perfect agreement	0.831
Risk of bias	Perfect agreement	1

Table 4

Moderator analysis of types of morphological complex words on the association between morphological awareness and reading comprehension, comparison of subgroups of types of morphologically complex words and the interaction between age and types of morphologically complex words

Moderator variable	*k*	*m*	I^2	τ^2	*F*	*r* 95% CI	*df*	*p*
Types of morphological complex words	112	51	73.10	.013	7.10		8.25	.016
Compounding	6	3				.433 [.029, .716]	2.00	.044
Derivation	72	34				.498 [.457, .536]	27.50	.001
Inflection	8	5				.580 [.563, .635]	3.10	.011
Inflection and derivation	26	22				.600 [.541, .640]	16.90	.001
Inflection and derivation vs. derivation					15.70		37.20	.001
Inflection vs. derivation					.91		3.72	.398
Inflection vs. inflection and derivation					.06		3.91	.815
Age and types of morphologically complex words	112	51			1.8		3.5	.291
Age and derivation							1.10	.220
Age and derivation and inflection							1.08	.130
Age and inflection							1.49	.777

Table 5

Moderator analysis of characteristics of morphological awareness tests on the association between morphological awareness and reading comprehension

Moderator variable	*k*	*m*	I^2	τ^2	*F*	*r* 95% CI	*df*	*p*
Input modality	105	48	78.16	.018	.092		14.60	.766
Visual	38	23				.529 [.468, .586]	18.69	.001
Both	16	10				.543 [.455, .621]	8.16	.001
Aural	51	22				.567 [.520, .611]	17.96	.001
Context	105	49	79.73	.018	2.35		9.49	.128
One sentence	10	5				.440 [.270, .584]	.3.74	.003
A pair of words	10	5				.461 [.175, .675]	2.78	.017
One uncompleted sentence with one word	35	26				.517 [.464, .566]	20.45	.001
One uncompleted sentence	28	20				.555 [.504, .603]	15.51	.001
One word	8	6				.572 [.327, .744]	2.83	.008
A pair of words with one single word	14	10				.578 [.509, .639]	7.05	.001
Word stimuli	113	51	78.95	.018				.372
Pseudowords	13	9				.507 [.399, .601]	6.75	.001
Real words	100	47				.548 [.515, .580]	42.27	.001
Output modality	114	51	80.46	.019				.180
Written	49	31				.525 [.476, .570]	26.40	.001
Oral	65	25				.566 [.524, .605]	21.8	.001
Nature of response	109	51	79.82	.018	1.60		4.07	.320
Yes/no decision	9	6				.406 [.052, .669]	3.50	.035
Producing a word	56	35				.527 [.483, .568]	28.50	.001
Read/repeat	6	4				.533 [.472, .589]	2.86	.001
Multiple-choice	31	20				.561 [.510, .608]	16.89	.001
Producing a sentence	7	5				.651 [.479, .775]	2.79	.003
Aspect of awareness	107	51	79.90	.019	4.81		5.03	.068
Awareness of morphemic units in words	14	9				.421 [.236, .576]	5.96	.002
Awareness of the relation of base words to their inflected and derived forms	54	36				.534 [.490, .576]	28.77	.001
Awareness of the meaning of affixes and the alterations in grammatical class they bring to base	32	22				.553 [.502, .600]	16.36	.001

words					
Awareness of the meaning of affixes and the alterations in meaning they bring to base words	7	5	.657 [.518, .762]	2.53	.002

Table 6

Moderator analysis of characteristics of reading comprehension tests on the association between morphological awareness and reading comprehension

Moderator variable	*k*	*m*	I^2	τ^2	*F*	*r* 95% CI	*df*	*p*
Passage length	114	51	79.77	.019				.680
Long	71	33				.537 [.498, .574]	28.50	.001
short	43	25				.551 [.491, .606]	20.70	.001
Response task	114	51	80.35	.019				.266
Question	78	38				.531 [.492, .568]	33.10	.001
Cloze	36	20				.569 [.509, .622]	16.10	.001
Response format	113	51	79.96	.019	1.78		9.24	.214
Producing an idea to an open-ended task	33	8				.484 [.386, .572]	6.27	.001
Selecting an idea to a question prompt	45	30				.541 [.498, .582]	26.29	.001
Producing a word in a cloze task	35	19				.568 [.507, .623]	15.44	.001

Figure 1

Flow diagram for the search and inclusion criteria for studies

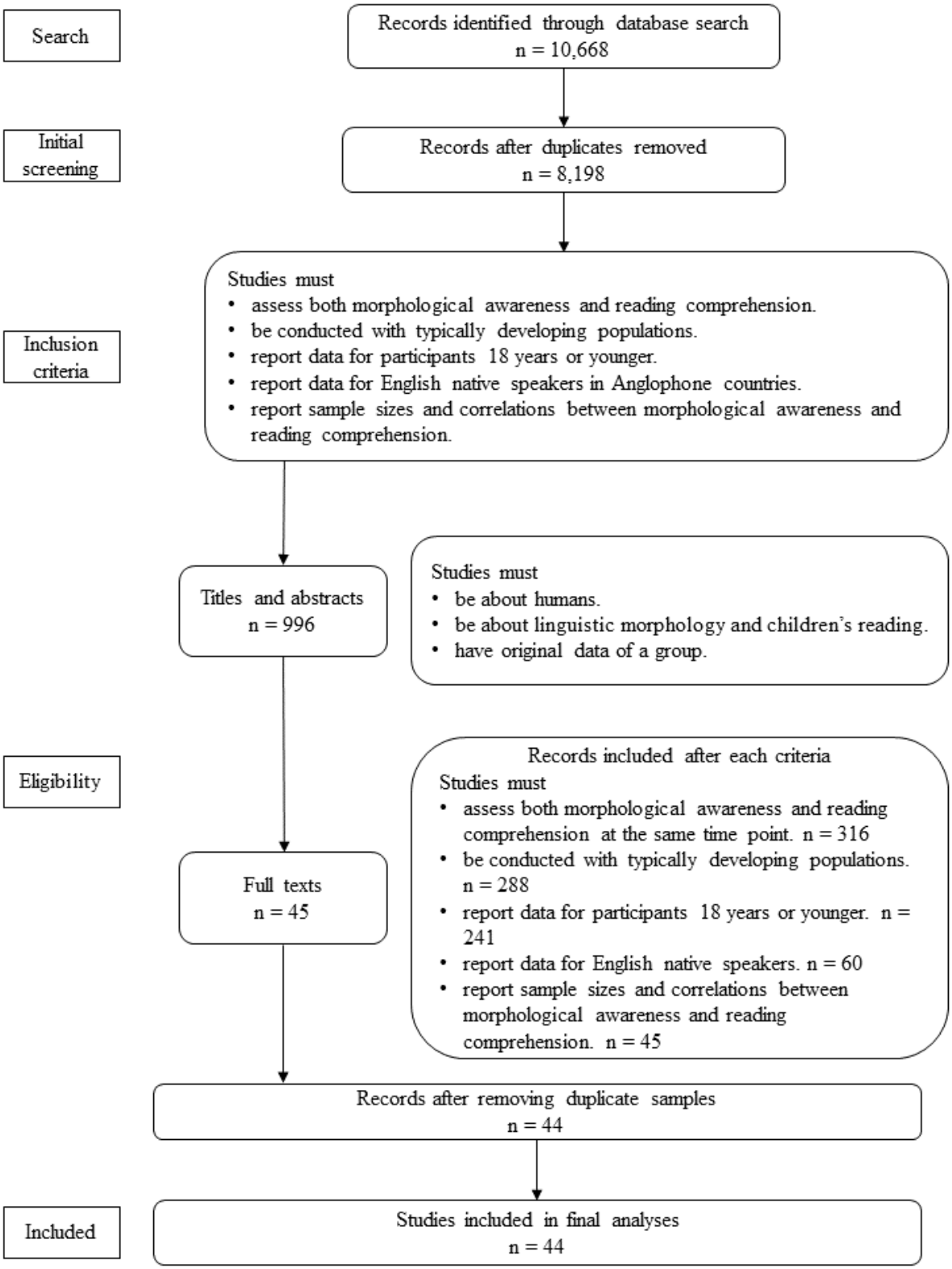

Figure 2

Grouped scatter plot of correlations between morphological awareness and reading comprehension versus mean age with estimated age and real age in black and red

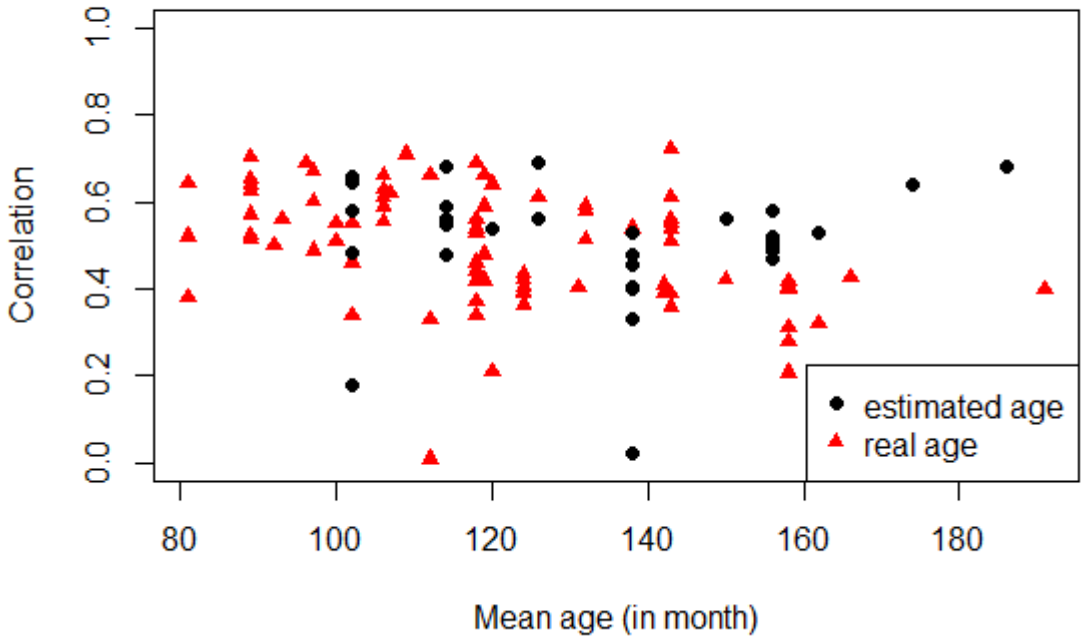

Figure 3

Grouped scatter plot of correlations between morphological awareness and reading comprehension versus mean age with aural input, visual input and both in black, green and red

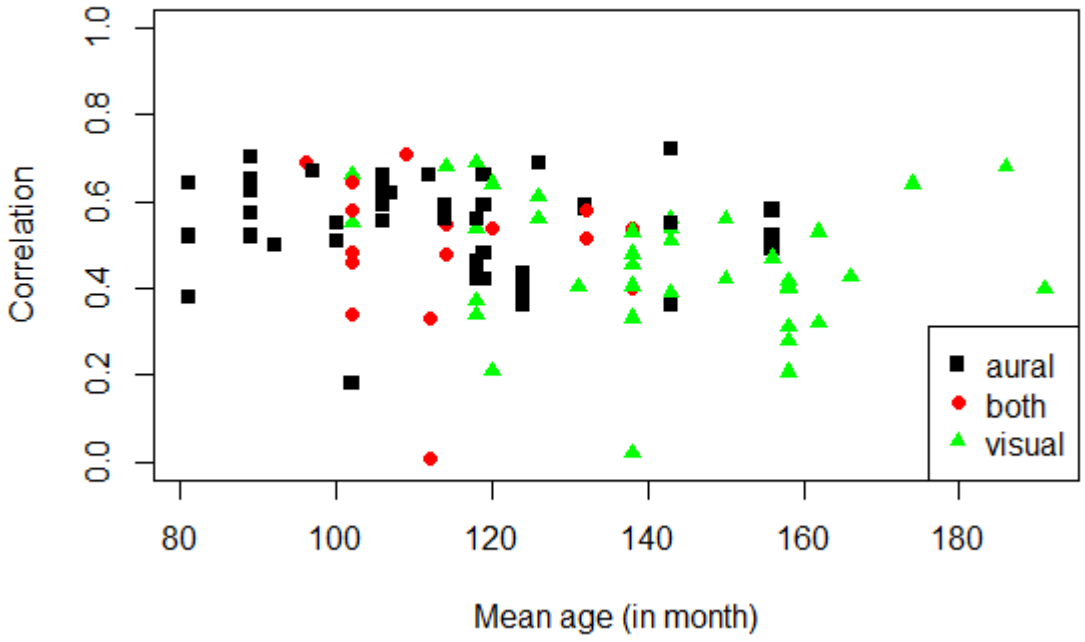

Figure 4

Grouped scatter plot of correlations between morphological awareness and reading comprehension versus mean age with oral output and written output in black and red

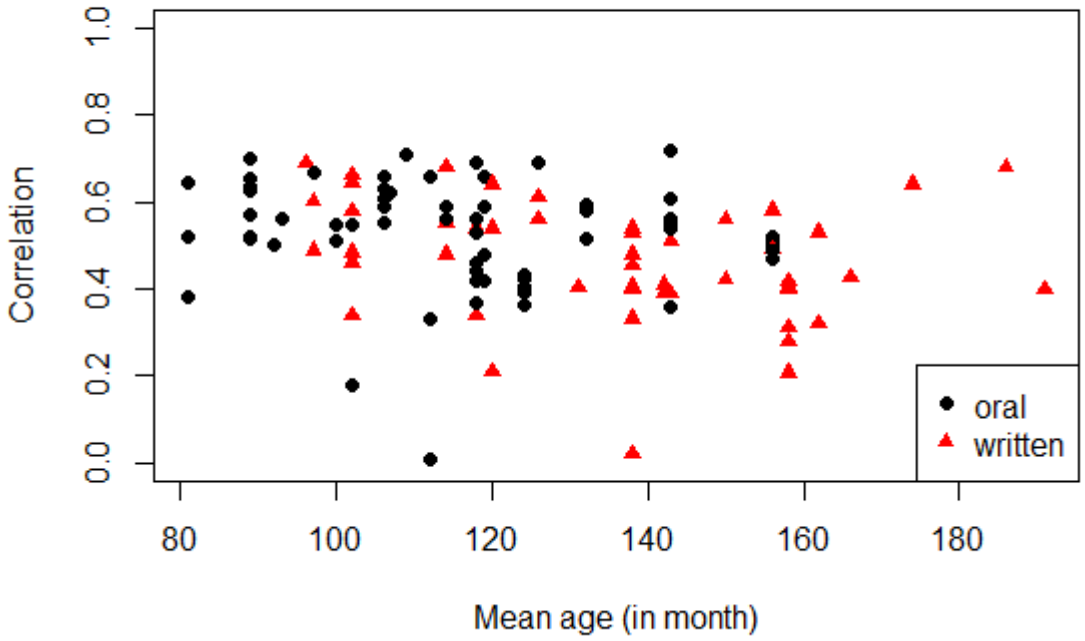

Figure 5

Funnel plot of all included studies