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The relations between morphological awareness and reading comprehension in beginner readers to young adolescents

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Background: Morphological awareness plays a crucial role in supporting higher-level text processing. We examined its contribution to reading comprehension in children of different ages and ability levels in order to determine when and for whom morphological awareness is of particular importance.
Methods: Three groups of children (aged 6–8 years, $N = 128$; 9–11 years, $N = 126$; and 12–13 years $N = 147$) completed judgement and production tasks to measure awareness of compounding, inflections and derivations. Nonverbal reasoning, vocabulary, phonological awareness, word reading and reading comprehension were also assessed.
Results: Principal component analysis yielded a single primary factor of morphological awareness for each age group. Separate hierarchical multiple regressions revealed that this morphological awareness factor accounted for significant unique variance in reading comprehension for groups of 6–8 and 12–13 years, beyond age, nonverbal reasoning, vocabulary, phonological awareness and word reading. Vocabulary also uniquely predicted reading comprehension in all three age groups. Quantile regression analyses at three points in the reading comprehension distribution (0.1, 0.5 and 0.9) indicated that morphological awareness and vocabulary predicted reading comprehension to a similar extent across the ability range.
Conclusions: Our results clarify the fundamental role of morphological awareness in reading comprehension across all levels of readers. In addition, vocabulary and morphological awareness each make critical contributions to comprehension ability in developing readers across the ability range.

Keywords: morphological awareness, reading comprehension, vocabulary, quantile regression

Highlights

What is already known about this topic

- Morphological awareness of inflections and derivations is significantly associated with reading comprehension but partly mediated by vocabulary knowledge.
- In general, morphological awareness becomes an increasingly important predictor of reading comprehension between 6 and 11 years.
- Children with poor reading comprehension exhibit weaknesses in morphological awareness.

What this paper adds

- Awareness of morphological compounding, inflections and derivations comprises a single factor in developing readers aged 6 to 13 years.
- Morphological awareness makes a unique contribution to reading comprehension ability beyond oral vocabulary and word reading skill.
- The relationship between morphological awareness and comprehension ability is evident and comparable in strength across the age range, and morphological awareness predicts reading comprehension across the ability range.

Implications for theory, policy or practice

- An appreciation of morphology should be taught from the earliest stages of reading instruction to early adolescence.
- Weak morphological awareness is an indicator of reading comprehension difficulties.
- Both good and poor comprehenders will benefit from enhanced morphological awareness.

An appreciation of morphemes – the units of meaning that that make up words, such as prefixes, roots and suffixes – is strongly related to reading ability in both children and adults (see Rastle, 2019, for a review). Models of reading comprehension describe two roles for morphology (Perfetti, Landi, & Oakhill, 2005). At a lexical level, it can support successful identification of boundaries in written words (e.g., distinguishing the *ea* in *reading* vs. *react*; Deacon & Kirby, 2004). As part of the broader linguistic system, morphology integrates meaning and syntax to support higher-level comprehension processes (e.g., Perfetti & Stafura, 2014). Our aim was to understand better how morphological awareness contributes to reading comprehension in three ways: (1) using different tasks and assessing different aspects of morphological awareness, we comprehensively examined morphological awareness in children across different ages (6–8, 9–11 and 12–13 years); (2) we examined whether morphological awareness was a unique predictor of reading comprehension above and beyond word reading ability and vocabulary knowledge; and (3) we evaluated the extent to which morphological awareness explained unique variance in reading comprehension at different points in the distribution of reading comprehension scores.

The development of morphological awareness

Morphemes are the smallest units of meaning in written and spoken language. For example, *'un'* is a morpheme that when added to a base word indicates *'not'*, as in *'unhappy'*. An appreciation of morphemes can support comprehension of complex English words such as *'unhappy'*, *'happier'* and *'happiness'*. Morphological awareness is a metalinguistic skill that represents the ability to reflect on and manipulate the morphemic structure of words (Carlisle, 1995). Awareness of three different types of morphology can be measured, with extant evidence suggesting slightly different developmental trajectories for each. The first is *compounding*, which involves combining two or more root morphemes to create a new word. For example, sunlight and moonlight both contain two morphemes – sun/moon and light – and the meaning of each compound word is a combination of the two morphemes. English-speaking children show an understanding of compound words in the preschool years, with age-related increases until approximately 5 years (Clark, Hecht, & Mulford, 1986). This early development is one reason why compounding is typically not included in studies of morphological awareness in school-age children, leaving its relationship with other aspects of morphological awareness and also reading comprehension unclear. We addressed this knowledge gap in this study.

The two other aspects of morphology more typically considered in studies of English speakers are *inflection* and *derivation*. Inflections provide information about, for example, number (cat–cats) and tense (like–liked) but do not change the word class of the base (e.g., 'cat' and 'like'). Derivations can change the word class of the base – for example, from a verb to an adjective or noun (*execute*: *executive* or *execution*) – and can also result in meaning change (*happy*: *unhappy*). Improvements on these aspects of morphology are evident across the school years (Kirby et al., 2012) up to ninth grade (Nagy, Berninger, & Abbott, 2006), with a particular increase in derivational morphology from around 8 years of age (Anglin, 1993; Berninger, Abbott, Nagy, & Carlisle, 2010). Thus, different aspects of morphological knowledge have different functions in relation to semantic and grammatical word class change. Further, we note that tasks to assess morphological knowledge differ in the extent to which they tap implicit or explicit knowledge (Carlisle, 2003) and also in the demands they place on semantic and grammatical understanding, which may influence whether developmental differences are captured (e.g., Tong, Deacon, Kirby, Cain, & Parrila, 2011). Thus, we followed recommendations to assess morphological awareness in more than one way (Apel, Diehm, & Apel, 2013). Given the seemingly different developmental trajectories of each aspect of morphological knowledge and variability in assessments, we sought to comprehensively assess morphological awareness in three different age groups. With these data, we were also able to explore whether the tasks tapped a common single construct or different (but related) factors, prior to establishing the relationship between morphological awareness and reading comprehension.

Morphological awareness and reading comprehension

Morphological awareness is related to reading comprehension ability across the school years (e.g., Foorman, Petscher, & Bishop, 2012) and into adulthood (Guo, Roehrig, & Williams, 2011). One proposed mechanism for this relation is the contribution of morphological awareness to accurate word reading (Singson, Mahony, & Mann, 2000), which lays the foundation for successful reading comprehension (Perfetti et al., 2005). Empirical studies support this view (e.g., Carlisle, 2000; Jarmulowicz, Hay, Taran, & Ethington, 2008), but the majority suggest that word reading only *partially* accounts for the relationship between morphological awareness to reading comprehension (Perfetti et al., 2005). For example, although the relationship between inflectional/derivational morphological awareness and reading comprehension is partially mediated via word reading in 8- and 9-year-olds, direct effects are still found (controlling for phonological awareness, receptive vocabulary and nonverbal reasoning; Deacon, Kieffer, & Laroche, 2014). Building on this, Levesque, Kieffer, and Deacon (2017) showed that morphological awareness predicts the decoding of morphologically complex words, which in turn predicts reading comprehension via general word reading. Importantly, both studies reported that morphological awareness contributed unique variance to reading comprehension *beyond* its indirect influence via word reading. Here, we control for word reading to better understand the unique contribution that morphological awareness makes to comprehension across age and ability.Morphological awareness necessarily involves vocabulary knowledge, and, as a result, measures of these two constructs tend to be highly correlated (Ku & Anderson, 2003; Nagy et al., 2006; Ramirez, Walton, & Roberts, 2014). Although there is conflicting evidence over their independence (Kieffer & Lesaux, 2012; Spencer et al., 2015), several studies support a unique contribution of morphological awareness to reading comprehension beyond vocabulary knowledge (e.g., Deacon et al., 2014; Kirby et al., 2012), and both indirect (through vocabulary) *and* direct pathways to reading comprehension have been modelled (e.g., Kieffer & Box, 2013; Nagy et al., 2006). These studies assessed receptive, reading or academic vocabulary and indicated that the unique relationship between morphological awareness and comprehension is not dependent on how the control measure of vocabulary was assessed. A limitation of much prior research is the use of real-word stimuli in the morphological awareness tasks (e.g., Deacon et al., 2014; Jarmulowicz et al., 2008; Kirby et al., 2012), making it hard to disentangle the relative contributions of vocabulary and morphological awareness to reading comprehension. We included both real and nonwords in the morphological awareness measures to minimise the extent to which performance on these tasks was simply a proxy for vocabulary knowledge (Bryant & Nunes, 2004).

The effect of morphological awareness on reading performance may change with age. The increasing exposure of children to written texts with an abundance of morphologically complex words has led to proposals that morphological awareness becomes a more important predictor of reading comprehension as literacy develops (Nagy et al., 2006). Although intuitively appealing, evidence in support of this developmental change is limited. Longitudinal studies rarely measure both constructs at multiple time points but provide some hints at a stronger relationship with increasing age. For example, Kirby et al. (2012) found that Grade 2, but not Grade 1, measures of morphological awareness explained unique variance in subsequent Grade 3 reading comprehension. In Deacon and Kirby's (2004) study, this influence emerged slightly later: morphological awareness in Grade 2 was predictive of reading comprehension in Grades 4 and 5, but not in Grade 3. However, cross-sectional studies including older children and adolescents have found only a sustained or even reduced influence of morphological awareness on reading comprehension in older age groups (Foorman et al., 2012; Nagy et al., 2006). We contribute to this seemingly conflicting literature by presenting a cross-sectional study of children from 6 to 13 years.

Morphological awareness and poor reading comprehension

The aforementioned studies reported a general relationship between morphological awareness and reading comprehension but did not examine whether this relationship was similar across the reading comprehension ability range. Tong et al. (2011) measured morphological awareness in Grade 5 children whose comprehension was weaker than predicted by their chronological age, word reading and nonverbal ability. These unexpectedly poor comprehenders were weaker than both average and unexpectedly good comprehenders on a word analogy task tapping knowledge of derivational morphology. A retrospective examination of their performance 2 years earlier demonstrated similar weaknesses. In contrast, no impairments were found on an analogy task measuring inflectional morphology, nor on a sentence completion task to assess morphological knowledge, which provided syntactic support. The relative specificity of poor comprehenders' difficulties to derivational morphology and its task-dependent nature has been replicated (Tong, Deacon, & Cain, 2014; MacKay, Levesque, & Deacon, 2017), supporting the proposal that derivational knowledge could be a key contributor to comprehension problems. Inflectional knowledge, in contrast, seems to be relatively intact for poor comprehenders, with some evidence that irregular inflections may pose an additional challenge for this group (Adlof & Catts, 2015; Nation, Snowling, & Clarke, 2005).

Whilst studies of morphological awareness in poor comprehenders have reported relatively consistent findings, this approach necessarily requires group selection based on somewhat arbitrary thresholds. A recent approach in developmental research is the use of quantile regression to assess how the predictive relationships might differ across the distribution of the outcome measure (Petscher & Logan, 2014). Rather than fitting a single regression model to describe the *average* prediction of ability, quantile regression fits several regression models weighted at different points in the ability distribution. Thus, all participants contribute to each analysis (as opposed to segregating small groups as in traditional poor comprehender research), with individual observations weighted by their distance from the specified percentile in each model (e.g., Language and Reading Research Consortium [LARRC] & Logan, 2017; Petscher & Kim, 2011). Only one study to our knowledge has taken this approach when assessing the relationship between morphological awareness and reading comprehension: Tighe and Schatschneider (2016) found that in adults with low literacy ability, morphological awareness contributed greater unique variance to reading comprehension than did vocabulary knowledge, in general. Further, morphological awareness was more predictive of performance at low levels of comprehension ability, whereas vocabulary was the stronger predictor at higher levels. We examine whether such a pattern is evident across the broader reading comprehension distribution, for children, and across development.

The present study

We examined morphological awareness and its relationship with reading comprehension ability across three age groups: 6–8, 9–11 and 12–13 years. We administered tasks that measured awareness of compounds, inflections and derivations using two tasks per morphology type: an analogy format that required production of the response, and a cloze judgement. These measures enabled us to characterise the development of morphological knowledge across this age range.

Principal component analysis was used to identify whether these tasks tapped single or multiple constructs at each age. To assess the stability of the relationship between morphological awareness and reading comprehension, we conducted hierarchical multiple regression models for each age group to assess whether morphological awareness made a unique contribution to reading comprehension beyond age, vocabulary ability, word reading and also phonological awareness and nonverbal reasoning. The latter two variables were included, in line with previous research (e.g., Deacon, Tong, & Francis, 2017; Kirby et al., 2012) for the following reasons. Phonological awareness was included as a control variable to determine whether our morphological awareness measure extended beyond knowledge of phonological rules (e.g., matching the addition of an *–s* sound) and was not simply representing general metalinguistic ability. Nonverbal reasoning was included to determine if the relationship between morphological awareness and reading comprehension was separate from the reasoning skills involved in performance on these tasks. We fitted regression models at three quantiles (0.1, 0.5 and 0.9) to test whether the relative contributions of morphological awareness and vocabulary knowledge differed according to comprehension ability in each age group. In doing so, we aimed to better understand when and for whom enhancing morphological awareness may be most beneficial for supporting reading comprehension.

Method

Participants

We recruited 128 six- to eight-year-olds (55 male; M_{age} = 7 years 5 months) from nine schools, 146 nine- to eleven-year-olds (74 male; M_{age} = 10 years 4 months) from 10 schools and 147 twelve- to thirteen-year-olds (65 male; M_{age} = 13 years 2 months) from three schools, all in the north-west of England in catchment areas to cover a range of low to high middle-class status. The study was approved by the local Research Ethics Committee. Parental consent was obtained for all participants (using opt-out for the 12- to 13-year-olds), and headteacher consent for all schools. Participating children gave their assent before each assessment. All children spoke English fluently, and children with special educational needs (teacher report) were not included in the study. As is clear from the standardised reading scores reported in Table 1, the children in each age group were performing at an appropriate ability level for their age.

Measures

Children completed individual and group-administered tasks to assess reading comprehension, word reading, phonological awareness, receptive vocabulary, nonverbal reasoning and morphological awareness. Unless otherwise stated, standardised tests were administered and scored according to the manual guidelines. Practice items with feedback were completed before each task. All measures had moderate to good reliability (Table 1). We used raw scores for analysis and report standardised scores to place our sample in wider context (Table 1).

Reading comprehension. The 6- to 8-year-olds and 9- to 11-year-olds completed the York Assessment of Reading for Comprehension (YARC) Passage Reading (Second Edition;

Table 1. Mean, standard deviation and range of scores for the background measures.

Measure	6–8 years	9–11 years	12–13 years	Reliability
Nonverbal reasoning				.67–.77[a]
Raw score	13.45 (3.71)	15.70 (3.69)	15.68 (2.88)	
	[2–22]	[3–22]	[6–21]	
Vocabulary				.72–.83[a]
Raw score	22.72 (4.22)	27.53 (5.30)	28.37 (3.89)	
	[13–32]	[16–36]	[18–36]	
Phon. awareness[b]				.87–.92[c]
Raw score	21.38 (6.26)	26.95 (4.99)	28.28 (3.89)	
	[4–33]	[13–34]	[16–35.01]	
Scaled score	10.47 (2.65)	9.89 (2.65)	9.39 (2.08)	
	[4–16]	[4–16]	[4–13.22]	
Word reading: word[d]				.90–.93[e]
Raw score	52.70 (14.96)	69.69 (10.91)	80.84 (9.05)	
	[15–78]	[36–93]	[57–107]	
Standardised score	111.09 (13.97)	99.92 (14.09)	103.00 (13.69)	
	[73–145]	[63–133]	[77–144]	
Word reading: nonword[d]				.89–.91[e]
Raw score	27.79 (11.85)	40.34 (11.89)	47.71 (9.45)	
	[5–58]	[9–61]	[27–66.18]	
Standardised score	109.95 (13.98)	104.78 (15.58)	105.31 (13.50)	
	[72–145]	[65–140]	[79–141]	
Comprehension[f]				.71–.90[c]
Ability score	49.11 (11.41)	60.06 (10.11)	61.04 (8.93)	
	[8–75]	[23–81]	[34–79]	
Standardised score	103.75 (11.56)	100.57 (12.00)	105.52 (9.20)	
	[70–130]	[70–128]	[79–124]	

Notes: Table presents mean, (*SD*) and [range] for each set of scores.
[a]Cronbach's α for sample.
[b]Comprehensive Test of Phonological Processing,
[c]Manual-reported Cronbach's α.
[d]Test of Word Reading Efficiency subtests.
[e]Manual-reported test–retest reliability. Standardised scores cannot be reported for nonverbal reasoning and vocabulary, as tests were not administered in the standardised form.
[f]York Assessment of Reading for Comprehension.

(Snowling et al., 2009), individually. Children read aloud two passages and answered eight comprehension questions after each. The recommended starting passage for the school year group was used. However, children who made more than the recommended number of word reading errors were assessed on lower-level passages. The YARC also provides measures of word reading accuracy and fluency, which are not included here owing to lack of comparable assessments for the oldest age group.

The reading comprehension of 12- to 13-year-old children was assessed using the YARC Secondary (Stothard, Hulme, Clarke, Barmby, & Snowling, 2010). Children read the two Level 1 passages recommended for this age group, silently, and answered 13 questions after each. Ten children who could not complete the recommended start passage owing to low word reading ability were excluded from our analyses.

Reading comprehension scores were converted to Rasch-based ability scores provided in the manual, which account for passage difficulty and performance across the two passages administered (see Cunningham & Carroll, 2015, for similar approach).

Word reading ability. Children completed the two subtests of the Test of Word Reading Efficiency Second Edition (TOWRE-2; Torgesen, Wagner, & Rashotte, 2012), in which they were required to read as many real words (Sight Word Efficiency [SWE]) or nonwords (Phonemic Decoding Efficiency [PDE]) as they could within 45 seconds. This measure is strongly correlated with non-speeded measures of word and nonword reading (e.g., LARRC, 2015).

Phonological awareness. Phonological awareness was assessed with the Phoneme Elision subtask from the Comprehensive Test of Phonological Processing Second Edition (Wagner, Torgesen, & Rashotte, 1999). Each item comprised a word spoken aloud by the assessor; children were asked to remove a sound from the beginning, middle or end to produce a different (real) word.

Vocabulary. Receptive vocabulary was measured by adapting the British Picture Vocabulary Scale Third Edition (Dunn, Dunn, Styles, & Sewell, 2009) for group administration (for similar modifications, see Stanovich & Cunningham, 1992). Children were shown 36 age-appropriate test items (four pictures per item) by using a projector. For each item, the assessor said a word aloud, and children were asked to circle the number (1–4) on a score sheet corresponding to the picture that best showed its meaning. One point was awarded per correct response.

Reasoning. Children completed a group-administered matrix reasoning task adapted from the Wechsler Intelligence Scale for Children – Fourth UK Edition (Wechsler, 2004). Children were shown a sequence of visual patterns and asked to select which of five patterns was missing from the sequence. Children worked individually through booklets of age-appropriate items at their own pace. The items selected started at the item recommended for each age group and continued until the item that would have enabled the oldest children in the group to attain a scaled score of 15. This resulted in 22 items for 6- to 8-year-olds, 23 items for 9- to 11-year-olds and 21 items for 12- to 13-year-olds. One point was awarded per correct response.

Morphological awareness tasks. Children completed experimenter-designed production and judgement tasks to assess awareness of compounds, derivations and inflections (six tasks in total). All age groups completed the same items. All real-word stems had an age of acquisition rating $<$ 6.5 years to be accessible to all age groups (Kuperman, Stadthagen-Gonzalez, & Brysbaert, 2012). Tasks to assess morphology measures can be presented in oral, written or combined oral and written forms (Kirby et al., 2012). For the oldest age group, all tasks were presented in written format only and administered in a group setting to minimise disruption to scheduled lessons: children worked through booklets individually at their own pace, circling (judgement tasks) or providing written responses (production tasks). For the two younger age groups, for whom word reading and writing ability are less well developed, the judgement tasks were also group administered with written presentation, but additionally read aloud by the assessor. For the production tasks, children were assessed individually, items were presented in oral and written form and children provided oral responses. We discuss the limitations of these differences in presentation format in the Discussion. The tasks are described in brief subsequently, with full details of test development, items and reliability (Cronbach's alpha) in supplementary materials (https://osf.io/t7uah/). One point was awarded per correct answer.

Compounds. Forty-eight conceivable but novel compounds were created by changing either the modifier or head of semantically transparent compound words. Two 24-item lists were created to provide two alternative forms of each task (production and judgement), counterbalanced across participants. For the 24 items in the production task, the target response was a novel compound. Children were given a frame (e.g., 'A wand that a fairy has is called a fairy wand. What is the name for a wand that an elf has?' Response: 'elf wand'). The judgement task was based on the Compound Structure Test (Nagy, Berninger, Abbott, Vaughan, & Vermeulen, 2003). For each of the 24 items, children were asked to choose which of two options best fitted the description (e.g., 'Which is a better name for a patch you wear over your ear? Ear patch or patch ear?').

Inflections. Forty-eight items across plural nouns, singular present tense and singular past tense (16 for each category) were created: 24 (eight for each) were real words and 24 were nonwords. We created two lists of 24 items, assigned to either the production or judgement task. For the production task, children were required to decompose the morphological relationship between a given pair of words and to use it to complete the pattern (Nunes, Bryant, & Bindman, 1997). Each of the 24 test items was paired with a real-word example: half involved the same suffix/change as the example, and another half required a different inflected form (e.g., *child: children*, *beach:* ______.). The judgement task was based on the Test of Morphological Structure (composition; Carlisle, 2000). For each of the 24 items, children were presented with the stem and an indicator of its word class (i.e., 'the' or 'to') and were asked to choose which of three options fitted the sentence best, selecting from the correct inflection and two incorrectly inflected forms (e.g., *To walk. Sophie had walking/walks/walked to school*.). The correct answer was presented in each position an equal number of times.

Derivations. Forty test items were created to assess the morphological transformations – noun to noun, noun to adjective, noun to verb, and verb to adjective – so that a comprehensive range was included. All suffixes occurred in the Children's Printed Word Database (Masterson, Stuart, Dixon, & Lovejoy, 2003). There were 20 real-word items and 20 that involved morphological transformations from novel stems analogous to real words. In line with Carlisle (2000), half of the items were phonologically transparent (e.g., *bag: baggage*, *streck: streckage*), and half required a phonological change (e.g., *obey: obedient*, *please: pleasant*). For the production task, children were presented with a pair of real words and asked to complete the analogical pattern (e.g., *drive: driver*, *run:* ____). There were 20 test items: 10 involved the same suffix as the pair, and 10 required a different suffix to be produced. For the judgement task (also 20 items), children were asked to choose which word fitted the sentence best from three variants: the correct answer, an incorrect answer formed by using a syntactically appropriate suffix that was inappropriate for the initial word class, and an inflected form (e.g., To farm. I want to be a *farmer/farmist/farming*.).

Results

The dataset and analysis code that support these findings are available at: https://osf.io/96542/.

Morphological awareness

Development of component skills. We first examined whether there were developmental improvements across each of the six measures of morphological awareness. Missing data (youngest, 1%; middle, 2.1%; and oldest, 1.3%) were dealt with via stochastic regression imputation, predicting each missing value on the basis of the other morphological awareness tasks and incorporating a random error term. Descriptive statistics for each task and age group are presented in Table 2. One-way analyses of variance demonstrated significant age effects for each task with the strongest performance from the older age group. Of note is the number at ceiling on the morphology compound tasks: 21% on the judgement task (compared with 2% youngest, 10% middle) and 48% on the production task (compared with 10% youngest, 34% middle). We return to this point in our discussion of limitations. Post hoc Tukey tests revealed significant differences between each successive age group for the compound judgement task ($F(2, 418) = 93.95$, $p < .001$) and the derivation production task ($F(2, 418) = 65.99$, $p < .001$). For all other tasks, the youngest group scored lower than the two older groups, which did not differ.

Dimensionality of morphological awareness. A principal component analysis was conducted for each age group (package *psych*; Revelle, 2018). The Kaiser–Meyer–Olkin test for sampling adequacy was good for each age group, with all scores ≥ 0.8. A single

Table 2. Mean proportion (standard deviation) and range of scores for the morphological awareness tasks.

Morphological awareness	6–8 years	9–11 years	12–13 years	$F(2, 418)$	p
Compounds					
Production	.77 (.22)	.91 (.11)	.94 (.12)	47.95	<.001
	[0–1]	[.46–1]	[.33–1]		
Judgement	.71 (.13)	.83 (.12)	.90 (.09)	92.94	<.001
	[.21–1]	[.5–1]	[.54–1]		
Inflections					
Production	.64 (.19)	.77 (.13)	.78 (.15)	35.82	<.001
	[.08–.96]	[.29–1]	[.33–1]		
Judgement	.71 (.17)	.87 (.12)	.87 (.11)	61.83	<.001
	[.25–.97]	[.46–1]	[.5–1]		
Derivations					
Production	.48 (.2)	.65 (.15)	.71 (.15)	68.5	<.001
	[.05–.85]	[.15–.90]	[.15–.95]		
Judgement	.54 (.2)	.77 (.14)	.79 (.12)	109.5	<.001
	[0–.95]	[.30–1]	[.30–1]		

morphology factor emerged in each age group (using eigenvalue > 1), with loadings for all tasks > .57 on this factor and the proportion of variance explained ranging from .48 to .63 (factor loadings range: 6–8-year-olds = .67–.84; 9–11-year-olds = .69–.85; and 12–13-year-olds = .57–.88). Given the extraction of a single component for morphological awareness in each age group, a factor score comprising these six measures was used in subsequent analyses.[1]

Unique contribution of morphological awareness to reading comprehension

To assess whether morphological awareness was a unique predictor of reading comprehension, we conducted a hierarchical regression analysis for each age group with YARC score as the dependent variable. As before, missing data were dealt with via stochastic regression imputation (youngest, 0.6%; middle, 1.4%; and oldest, 2.8%). We used raw scores for nonverbal reasoning, vocabulary and phonological awareness measures. We formed a composite *z*-score for word reading from the two TOWRE subtest raw scores (SWE and PDE), owing to high correlations in each age group (*r*s all; >.76). All variables were centred and scaled prior to modelling and inspected for issues for multi-collinearity (correlations available online at https://osf.io/yv2m7/). For each age group, we entered age as the first step in the model, followed by nonverbal reasoning, vocabulary, phonological awareness and the word reading composite. We entered the morphological awareness factor score as a final predictor to determine whether it made a unique contribution to reading comprehension ability. The final models showed slight evidence of non-normality (all ages) and heterogeneity of variance (oldest age group only), so bias-corrected and accelerated bootstrap confidence intervals were used to determine significant predictors of comprehension ability (package *car*; Fox & Weisberg, 2019).

All background ability measures explained additional variance in reading comprehension for the youngest group when entered in a stepwise manner, whereas word reading did not predict performance in the two older groups, and phonological awareness did not predict performance in the oldest age group (Table 3). The final models are plotted in Figure 1 and predicted 61%, 42% and 40% of variance in reading comprehension for the youngest, middle and oldest groups, respectively. With all variables included, age held as a significant predictor of performance for the middle and oldest age groups, and vocabulary accounted for unique variance in reading comprehension for all three groups. Morphological awareness made small but significant contributions to the prediction of reading comprehension for the youngest (change in adjusted R^2 = .06) and oldest (.04) groups. For the middle age group, the contribution was weaker (.01) and was not statistically significant.

Contribution of morphological awareness to reading comprehension across comprehenders of varying ability

The aforementioned hierarchical regressions speak to how well morphological awareness and the control measures predict reading comprehension ability on average but do not address whether these relationships might differ for children with poor or very good reading comprehension. To assess this, we fitted quantile regression models at the 0.1, 0.5 and 0.9 quantiles and tested whether vocabulary and morphological awareness made different

[1]We report correlations for all morphology tasks for each age group at https://osf.io/9e6fr/.

Table 3. Hierarchical multiple regression for the prediction of reading comprehension in all age groups.

Age group	Step, predictor	Reading comprehension		
		ΔR^2	Final β	95% CIs
6–8 years	1. Age	.11***	.11	[−0.02, 0.22]
	2. Reasoning	.07**	.02	[−0.16, 0.17]
	3. Vocabulary	.25***	**.26**	[0.09, 0.41]
	4. PA	.08***	.06	[−0.06, 0.23]
	5. Word reading	.04***	.09	[−0.06, 0.24]
	6. MA	.06***	**.44**	[0.25, 0.69]
9–11 years	1. Age	.13***	**.13**	[0.03, 0.26]
	2. Reasoning	.18***	.16	[−0.01, 0.39]
	3. Vocabulary	.07***	**.30**	[0.14, 0.45]
	4. PA	.02*	.16	[−0.02, 0.39]
	5. Word reading	.00	−.12	[−0.37, 0.09]
	6. MA	.01	.20	[−0.08, 0.45]
12–13 years	1. Age	.03*	**.16**	[0.02, 0.31]
	2. Reasoning	.12***	.14	[−0.05, 0.32]
	3. Vocabulary	.18***	**.34**	[0.19, 0.50]
	4. PA	.01	.08	[−0.10, 0.25]
	5. Word reading	.00	−.04	[−0.19, 0.17]
	6. MA	.04**	**.26**	[0.04, 0.45]

Notes: Final βs in bold mark significant predictors in final model. Final βs and CIs derived from bootstrapped (bias-corrected) models.
PA, phonological awareness; MA, morphological awareness.
* $p < .05$.
** $p < .01$.
*** $p < .001$ in stepwise regression.

contributions across the ability spectrum (using package *quantreg*; Koenker, 2018). We focused on these two variables in line with Tighe and Schatschneider (2016), and because they emerged as the key predictors in the hierarchical regressions. However, we also included two additional control variables: age, given that it remained a unique predictor of performance in two of the aforementioned regression analyses, and word reading, to facilitate interpretation across age groups in light of different comprehension test formats (i.e., reading silently vs. aloud with correction). We first describe the results at each quantile, before analysing whether the regression slopes are significantly different between quantiles.

The coefficients for each quantile in each age group are plotted in Figure 2, and the values are reported in Table 4. We urge caution in the interpretation of the goodness-of-fit (R^2) values because currently there is no agreed procedure for the calculation of this statistic for quantile regression. For the youngest group, morphological awareness was a significant predictor of reading comprehension across all three quantiles, whereas the contribution of vocabulary was statistically significant only at the 0.9 quantile. A similar pattern was observed for the middle age group: morphological awareness appeared to predict reading comprehension in the lower two quantiles (although we note this was not statistically significant for the lowest ability group, $p = .051$), whereas only vocabulary

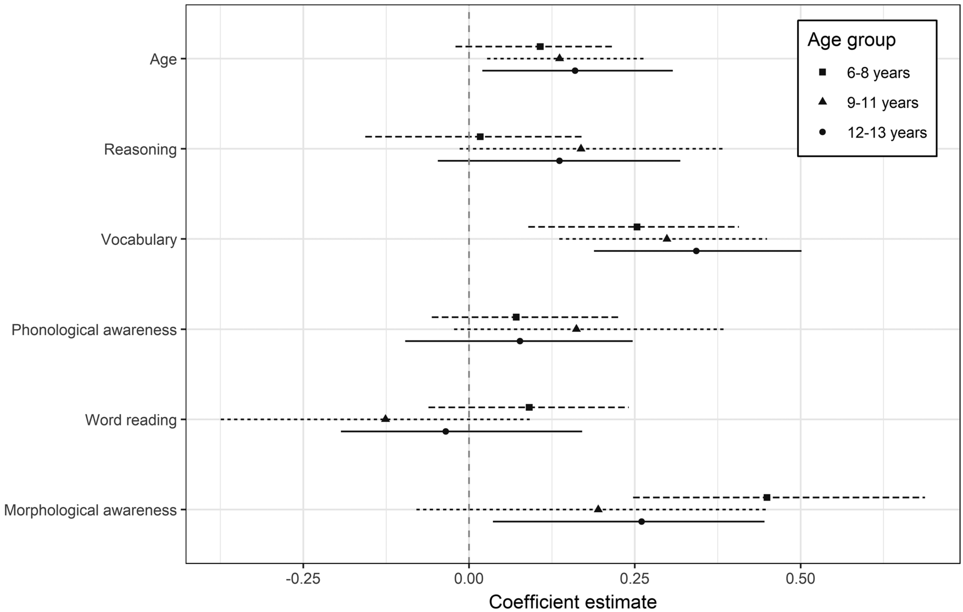

Figure 1. Dot-and-whisker plot to show predictors of comprehension ability in the linear regression models for each age group. The central 'dot' marks the β-coefficient, and the 'whiskers' extend to the bootstrapped 95% confidence intervals. This means that whiskers that do not cross the 0 coefficient boundary are statistically significant predictors of reading comprehension for that age group.

predicted reading comprehension at the highest quantile. For the oldest group, morphological awareness predicted comprehension for the lower two quantiles, but vocabulary was only a significant predictor at the 0.5 quantile. However, despite some differences in prediction at each quantile individually, the regression slopes did not significantly differ across quantiles. As such, the results suggest that morphological awareness and vocabulary predict reading comprehension to a similar extent across the ability range.

Discussion

We examined the unique contribution of morphological awareness to current reading comprehension in children aged 6–8, 9–11 and 12–13 years. For each age group, we found a single factor structure of morphological awareness. Of note, the resulting factor score made a significant and unique contribution to reading comprehension, over and above word reading, vocabulary, phonological awareness and nonverbal reasoning scores in each age group. An additional contribution to the literature was the finding from our quantile regression analyses showing that morphological awareness predicted performance across the reading comprehension ability range for each age group. We discuss subsequently how these findings extend our understanding of morphological awareness and its influence on reading comprehension, as well as educational implications.

Unlike most previous research that has studied just a single aspect of morphology or used a single task, we assessed different types of morphological awareness (compounding, inflections and derivations) across two types of responses elicited (production and judgement). This approach enabled us to comprehensively examine the construct of

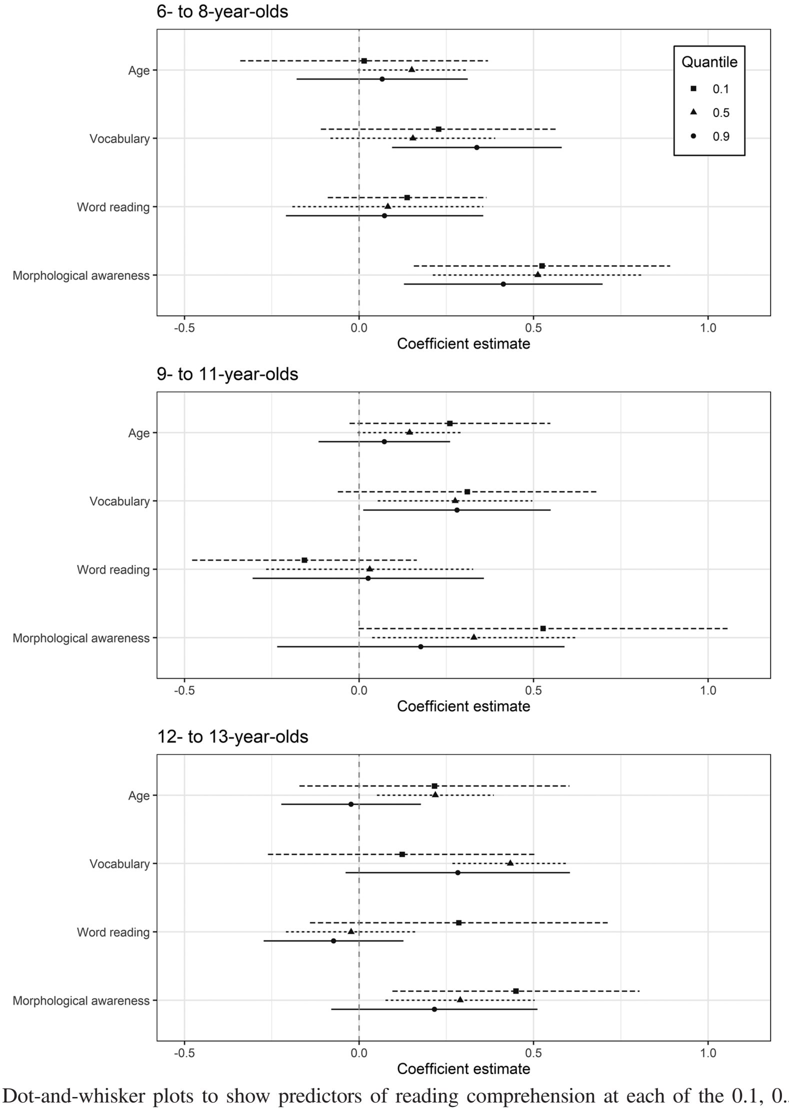

Figure 2. Dot-and-whisker plots to show predictors of reading comprehension at each of the 0.1, 0.5 and 0.9 quantiles for the three age groups separately.

morphological awareness and to improve the robustness and generalisability of findings. In line with previous research, we found a developmental progression in performance (Anglin, 1993; Berninger et al., 2010; Kirby et al., 2012; Nagy et al., 2006), indicating that our tasks provided sufficient challenge to capture variability in performance in each age group. Our principal component analysis revealed a single dimension of morphological awareness for each age group, across different aspects of morphological awareness and regardless of the format of assessment. The use of a single score across a comprehensive assessment of this construct enabled us to capture a range of performance levels in each age group. Despite the limitation of strong performance on the compounding task for the older age group, we believe our tasks had sufficient sensitivity to capture variation in ability.

Table 4. Regression models for the prediction of reading comprehension at 0.1, 0.5 and 0.9 quantiles in each age group.

Age group, quantile	Predictor	β	SE	Goodness of fit
6–8 years				
0.1	*Intercept*	−.81	0.17	0.38
	Age	.01	0.18	
	Vocabulary	.23	0.17	
	Word reading	.14	0.11	
	MA**	**.52**	0.19	
0.5	*Intercept*	.04	0.07	0.38
	Age	.15	0.08	
	Vocabulary	.15	0.12	
	Word reading	.08	0.14	
	MA**	**.51**	0.15	
0.9	*Intercept*	.68	0.11	0.40
	Age	.07	0.12	
	Vocabulary**	**.34**	0.12	
	Word reading	.07	0.14	
	MA**	**.41**	0.14	
9–11 years				
0.1	*Intercept*	−.90	0.16	0.25
	Age	.26	0.15	
	Vocabulary	.31	0.19	
	Word reading	−.16	0.16	
	MA	.53	0.27	
0.5	*Intercept*	.07	0.08	0.27
	Age	.14	0.08	
	Vocabulary*	**.28**	0.11	
	Word reading	.03	0.15	
	MA*	**.33**	0.15	
0.9	*Intercept*	.90	0.13	0.18
	Age	.07	0.10	
	Vocabulary*	**.28**	0.14	
	Word reading	.03	0.17	
	MA	.18	0.21	
12–13 years				
0.1	*Intercept*	−1.04	0.14	0.26
	Age	.22	0.20	
	Vocabulary	.12	0.19	
	Word reading	.29	0.22	

(*Continues*)

Table 4. (Continued)

Age group, quantile	Predictor	β	SE	Goodness of fit
	MA*	**.45**	0.18	
0.5	*Intercept*	.03	0.08	0.23
	Age*	**.22**	0.08	
	Vocabulary***	**.43**	0.08	
	Word reading	−.02	0.09	
	MA**	**.29**	0.11	
0.9	*Intercept*	.97	0.11	0.20
	Age	−.02	0.10	
	Vocabulary	.28	0.16	
	Word reading	−.07	0.10	
	MA	.22	0.15	

Notes: Goodness-of-fit statistic computed for quantiles according to Koenker and Machado (1999), analogous to R^2. Significant effects in bold.
*$p < .05$.
**$p < .01$.
***$p < .001$.

Our findings align well with contemporary theoretical models of reading positing metalinguistic constructs – such as phonological and morphological awareness – as levels of representation essential to reading (e.g., Perfetti & Stafura, 2014). Our regression analyses using the factor scores demonstrate how an underlying construct of morphological awareness is related to reading comprehension. The single factor of morphological awareness found here does not advocate that future studies should include only a single aspect of morphology or task, however. Given that each of the six tasks had a loading of >.57 on the single factor for each age group, indicating that compounding, inflections and derivations each made a significant contribution, we recommend the use of multiple morphological awareness tasks.

Like some previous studies (e.g., Berninger et al., 2010; Deacon & Kirby, 2004; MacKay et al., 2017), the reliability of some of our morphological awareness tasks was low (<.70). This may reflect the wide range of modifying relationships (for compounds) and parts of speech (for compounds, inflections and derivations) that we included as items to provide a comprehensive assessment of this construct. Studies of the dimensionality of other aspects of language such as word knowledge (Kieffer & Lesaux, 2012) and inference making (LARRC & Muijselaar, 2018) demonstrate a similar pattern where common variance exists for a core construct, yet both theoretical and statistical distinctions between different aspects of that construct are also evident. Our findings offer a starting point for future research to directly investigate the dimensional construct of morphology clarifying how the development of knowledge about compounding, inflections and derivations is related to the parts of speech involved.

Our quantile multiple regression approach was novel and enabled us to extend our understanding of the role of morphological awareness in reading comprehension. Whereas previous studies have focused solely on the average influence of morphological awareness on reading comprehension by contrasting morphological awareness scores across different reader groups (poor, typical and good comprehenders), we were able to examine the contribution of morphological awareness across the ability range. Our findings do not contradict studies that have reported deficits in morphological awareness for poor comprehenders when compared with better comprehenders; rather, they demonstrate the critical influence of morphological awareness on reading comprehension across different ability levels. In addition, by controlling for vocabulary in our analyses and including nonword items in our materials, we have demonstrated the specific influence of morphological knowledge on reading comprehension.

The pattern of findings in our quantile multiple regressions broadly mirrored that reported for low literacy adults (Tighe & Schatschneider, 2016): morphological awareness was a stronger predictor of reading comprehension in poorer readers, whereas vocabulary was the stronger predictor for older readers. However, in contrast to that study, the contributions of morphological awareness and vocabulary did not differ statistically across the ability distribution. Different sampling approaches may underlie these differences: adults with a history of weak literacy versus children and adolescents sampled by allowing reading skill to vary. The predictive power of morphological awareness across the distribution aligns with studies that have used quantile regression to study the prediction of reading comprehension: for example, oral language skills predict performance across the reading comprehension ability range in 8 to 9-year-olds (LARRC & Logan, 2017), even when word reading is controlled. Our findings, together with previous research, confirm the critical influence of morphological awareness on children's reading comprehension and support recommendations to include this as a focus of classroom instruction (e.g., Bowers, Kirby, & Deacon, 2010).A key debate in research on morphological awareness revolves around the extent to which knowledge and awareness of morphemes, rather than simply language *per se* (i.e., metalinguistic awareness), influence reading ability. We included a measure of phonological awareness to take shared variance associated with metalinguistic awareness into account. Consistent with previous research (e.g., Deacon et al., 2014; Deacon & Kirby, 2004; Kirby et al., 2012), the influence of morphological awareness on reading comprehension remained even after controlling for phonological awareness and vocabulary. Also, increasing attention has turned to examine how morphological awareness might influence other aspects of language development: for example, how the ability to reflect on the morphological structure of words may be a tool for vocabulary growth by inferring meaning through morphological problem solving (Anglin, 1993; Levesque, Kieffer, & Deacon, 2019). Determining the specific aspect of and extent to which morphological awareness supports current language and literacy performance and growth would both enhance our theoretical understanding of language and literacy development and also inform classroom practice.

In addition to the implications for future research and education detailed earlier, we note the following limitations and also highlight additional educational implications. We did not examine consecutive age groups nor follow our sample longitudinally. Such designs could elucidate any diachronic change in the relations between morphological awareness and reading ability, and the underpinning developmental mechanisms. However, the findings reported here clearly indicate the importance of morphological awareness across a wide developmental age range, in part because we developed tasks that captured variability in each age group. Thus, and in line with others, our findings highlight the potential importance of teaching morphological awareness to support reading comprehension (e.g., Bowers et al., 2010). Our findings further indicate that instruction in morphology may benefit the entire ability range, not just the poorer comprehenders, and that morphological awareness should be taught from the earliest stages of reading instruction to at least early adolescence.

Further, we note that whilst the oldest age group were presented with items in written format, the presentation was oral and written for the two youngest age groups. Despite this difference in presentation, there was a common finding that morphological awareness predicted reading comprehension at different levels of ability in each age group, after controlling for word reading, vocabulary, phonological awareness and nonverbal reasoning scores. Our use of quantile regression to study these research questions was novel, although we note limitations in the interpretation of values such as goodness-of-fit values due to a lack of consensus in the field. Finally, we note that the variance in reading comprehension explained decreased from the youngest to older age groups. Of course, this may in part be due to differences in presentation format. However, we speculate that another reason for this finding is that strategy knowledge and background knowledge are a greater influence on older children's comprehension, typically assessed with longer and more complex texts, on less familiar topics.

In sum, we demonstrated a single factor structure for morphological awareness for children aged 6 to 13 years, informed by knowledge of compounding, inflections and derivations across different tasks. This predicted unique variance in reading comprehension across the ability range. Our results clarify the fundamental role of morphological awareness in reading comprehension across all levels of readers and support calls for instruction in morphology even for beginner readers.

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