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Awareness and analysis: concurrent and predictive roles of two morphological processes in early reading comprehension

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Introduction: We examine how awareness and analysis of morphemes contribute to children's reading comprehension and its development. A multidimensional perspective on reading comprehension posits morphological awareness and morphological analysis play distinct roles in reading comprehension. Assuming individual differences in growth in these aspects of morphological processing, their concurrent influences can vary depending on children's reading comprehension abilities, and predictive influences can change as children's reading comprehension abilities improve.

Method: The current longitudinal study examined the concurrent and predictive influences of awareness and analysis on children's reading comprehension from Grades 1 to 3. Data from 171 public school children, with diverse reading comprehension abilities, were collected across five waves and were analyzed using cross-lagged panel structural equation modeling.

Results: Results showed concurrent relationships among morphological awareness, analysis, and reading comprehension in Grades 1 and 2, and morphological analysis having a concurrent relationship with reading comprehension at the end of Grade 3. Morphological awareness in all waves but Wave 3, at the end of Grade 2, predicted subsequent reading comprehension. Morphological analysis did not predict subsequent reading comprehension.

Discussion: Findings support the multidimensional conceptualization of awareness and analysis as distinct morphological processes that play early-wave concurrent and across-wave predictive roles in children's reading comprehension development.

KEYWORDS

reading comprehension, morphological awareness, morphological analysis, longitudinal research, child development

Introduction

Children with good reading comprehension skills make efficient semantic use of the material they read, access new information, and ultimately achieve academic and individual goals. Good comprehension of written and spoken language is facilitated by knowledge of morphemes, the smallest units of meaning in spoken and written language (Carlisle, 2003; Kirby et al., 2012). Knowing how morphological skills develop and how these skills contribute to developmental change in reading comprehension is important to better understand factors that contribute to reading comprehension and its growth in good and poor readers, and to help establish effective teaching methods and interventions for children who struggle with reading comprehension. We used a longitudinal design to examine how two aspects of morphological processing, awareness and analysis, contribute to children's early reading comprehension.

Morphological processes and reading

Approximately 80% of English words are multi-morphemic, making the understanding of morphemes critical to novel-word decoding and meaning extrapolation (Anglin, 1993; Kirby and Bowers, 2017; Hiebert et al., 2018). Understanding morphemes provides children with segments of regularity, including rule-based sublexical structures, that facilitate identification of complex unfamiliar words (Levesque et al., 2021), allow words to be morphologically organized and stored in memory, and enable efficient retrieval of word identities and meanings (Elbro and Arnbak, 1996; Kuo and Anderson, 2006). With further morphological skill development, children become more efficient in parsing complex multimorphemic words to extrapolate meaning and other word-related information for reading, writing, and speaking (Carlisle, 2003).

Morphological understanding is critical to children's reading development (Carlisle and Goodwin, 2013; Carlisle and Kearns, 2017; Duncan, 2018; Levesque et al., 2021) particularly to inference making and meaning manipulation in spoken and written language (Kuo and Anderson, 2006; Kieffer and Lesaux, 2012). It supports decoding, influencing phonological and orthographic processing, and semantic/syntactic understanding that facilitates reading comprehension (Nagy et al., 2003; Deacon et al., 2014). Hence, there are varied ways in which morphological understanding can support developmental change in decoding, reading comprehension and language production abilities (Carlisle, 2003). Despite research showing contributions of morphological processing to reading growth, morphology continues to be underrepresented in conceptualizations of reading development and intervention (Kuo and Anderson, 2006; Carlisle, 2010; Carlisle and Kearns, 2017; Ehri, 2020). Explicit teaching of morphological skills can improve reading outcomes (Bowers et al., 2010; Goodwin and Ahn, 2013; Nagy et al., 2014; Ramirez et al., 2014). Because morphological instruction can take many forms, better understanding of how specific morphological processes contribute to reading comprehension can guide effective instructional decisions across development.

The multidimensionality of morphological processes

A multidimensional perspective posits multiple facets of morphological processing have unique contributions to reading (Tighe and Schatschneider, 2015; Goodwin et al., 2017, 2020; Levesque et al., 2021). Morphological processing is assumed to involve at least two aspects, awareness and analysis, as distinct aspects of morphological processing that contribute to reading comprehension throughout development. Their roles may change as reading comprehension and morphological skills evolve in children.

Morphological awareness

Morphological awareness is the ability to reflect upon and manipulate morphemes and to understand that morphemes are the building blocks of language (Carlisle, 2000; Kuo and Anderson, 2006; Kirby et al., 2012). It is critical to children's knowledge of word formation in spoken and written language (Carlisle, 2003), of relations among words in discourse, and ability to manipulate morphemes to produce correct word forms to fit within sentence contexts (Carlisle, 1995; Kuo and Anderson, 2006). It allows readers and speakers to understand word structure and formation and manipulate the smallest units of meaning in language (Carlisle, 2003).

Morphological awareness is typically measured using tasks that require oral manipulation of morphemes or identification of morphemes in words (e.g. "Enter," "He greeted me when I ___." [entered], or "Is there a little word in ___ that means something like ___?" [pulled – pull]) (Carlisle and Fleming, 2003). With these measures, it is reasonable to assume awareness of units of meaning and ability to use morphemes productively contributes to understanding meaning in text and supports reading comprehension, especially during development (Carlisle, 2003).

Research on the relationship between morphological awareness and reading comprehension typically focuses on children whose foundational reading skills in decoding and fluency are relatively well developed. This research demonstrates that morphological awareness contributes to reading comprehension both concurrently and as a unique predictor of reading achievement in middle- to late-elementary school years (Nagy et al., 2006; Kieffer et al., 2016). Children show sensitivity to morphological irregularities, and their morphological awareness contributes to early reading comprehension (Treiman and Cassar, 1996; Deacon and Bryant, 2006; Deacon, 2008; Ramirez et al., 2014). Morphological awareness and reading comprehension are related in younger children, who concurrently develop reading and morphological skills in the earliest school years. Deacon et al. (2018) examined the direct contribution of children's morphological awareness to reading comprehension from age 5 to 7 when reading-related skills are developing. They found that morphological awareness significantly contributed to reading comprehension even after controlling for word-level reading.

Morphological awareness is a unique longitudinal predictor of reading comprehension skills (Foorman et al., 2012; Kirby et al., 2012; Kruk and Bergman, 2013; Deacon et al., 2014; Levesque et al., 2017). Recent confirmation across multiple developmental periods shows morphological awareness contributes to reading comprehension across ages (6–8 years, and 12–13 years) and reading abilities (James et al., 2021). Stronger morphological awareness enables readers to accurately identify the semantic and syntactic roles of words in context to facilitate reading comprehension, likely supporting the transition from novice to expert reading ability (Castles et al., 2018; Levesque et al., 2021). However, most studies examine unidimensional conceptualizations of morphological processing, focusing on morphological awareness without considering the contributions of other morphological processes to reading comprehension.

Morphological analysis

Morphological analysis involves using morphemes to infer meaning from unfamiliar and/or morphologically complex words (Anglin, 1993; Baumann et al., 2002; Carlisle, 2007; Pacheco and Goodwin, 2013; Deacon et al., 2017; Levesque et al., 2019, 2021). It is conceptualized as a problem-solving ability to determine word meanings by applying knowledge of morphological components (Crosson et al., 2021). As children gain morphological understanding and become familiar with morphological regularities, they use this knowledge to infer the meaning of morphologically complex words. For example, children who have never encountered the word "unfairness" may use their understanding of the morphemes that make up the word ("un," "fair," and "ness") to extrapolate its meaning (McCutchen and Logan, 2011; Pacheco and Goodwin, 2013; Levesque et al., 2019). Morphological analysis is typically measured by asking participants to produce or choose definitions for morphologically complex words tapping into their ability to analyze multimorphemic words to derive meaning (McCutchen and Logan, 2011; Pacheco and Goodwin, 2013; Levesque et al., 2019).

Morphological awareness and analysis in reading comprehension

Multimorphemic words are encountered most frequently when reading (Levesque et al., 2021). Because readers gain morphological knowledge, skills in morphological processing, and familiarity with morphological consistencies at varying rates across time, morphological awareness and analysis may facilitate reading comprehension of novel or complex text in different ways at different points in children's development. Morphological awareness, which involves parsing multimorphemic words and manipulating their constituent parts, and morphological analysis, which involves processes that involve inferring meaning, likely contribute differently to children's reading comprehension (Goodwin et al., 2017; Levesque et al., 2021).

Studies of the distinct roles of awareness and analysis in reading comprehension and its development typically focus on children who have established basic reading skills, by about Grade 3 and beyond (Levesque et al., 2017, 2019). Deacon et al. (2017) evaluated the influences of morphological awareness, analysis, and morphological decoding (an additional aspect of morphological processing in reading) in children in Grade 3 and Grade 5. They found that morphological analysis and morphological decoding, and not morphological awareness, uniquely contributed to participants' reading comprehension abilities, after controlling for phonological awareness, nonverbal cognitive ability, and word reading. Older children in Grade 5 and Grade 8 can extract meaning from morphologically complex words by choosing definitions for low-frequency unfamiliar words within sentence contexts; hence, morphological analysis ability accounts for unique variance in reading comprehension (McCutchen and Logan, 2011). Goodwin et al. (2020) found an additive contribution of both morphological awareness and analysis to reading comprehension in Grade 8 students, suggesting that each aspect makes unique contributions to reading comprehension at this age.

Levesque et al. (2019) sought to determine which aspects of morphological processing contributed to gains in reading comprehension over time. They found that while morphological awareness contributed to improvements in morphological analysis, only morphological analysis contributed to reading comprehension from Grade 3 to 4, when controlling for prior ability. In contrast, morphological awareness, analysis, and reading comprehension were assessed in students in Grade 4 and 5 with varied English proficiency; students with stronger English proficiency were better able to use morphological analysis to infer word meaning compared to those with limited English proficiency (Zhang et al., 2020). Regardless of English proficiency level, Zhang et al. (2020) found that the relationship between morphological awareness and reading comprehension was mediated by morphological analysis for these students. To further clarify the contributions of morphological awareness and analysis to reading comprehension in early development, research is needed during early literacy acquisition to better understand how these two aspects change over the course of development and how they contribute to change in reading comprehension skill over time.

Theoretical conceptualizations of reading comprehension and the contributions of morphological processes can be contextualized within broader connectionist/PDP (e.g., Joanisse et al., 2000; Jared et al., 2017) and decomposition (e.g., Rastle et al., 2000; Beyersmann et al., 2016) approaches to morphological processing in reading. A recent model for morphological processing in reading comprehension, Levesque et al.'s (2021) morphological pathways framework, derived from Perfetti's reading systems framework (Perfetti and Stafura, 2014), describes distinct roles of awareness, providing direct access to text comprehension, analysis, with indirect access to text comprehension through use of lexical representations of syntactic, morphological, and semantic information, and morphological decoding, with indirect access to text comprehension through facilitation of written word identification. We focus here on awareness and analysis as primarily spoken-language morphological processes to examine developmental change in their roles in reading comprehension, from early reading to more-skilled reading in the first 3 years of children's reading development from Grade 1 to Grade 3. Morphological awareness may be especially useful early in development when word-specific knowledge applied to reading comprehension is predominant, and morphological analysis may be especially useful for reading comprehension later in development when children encounter more-complex words in sentence contexts, have acquired more vocabulary knowledge, and make use of additional levels of language knowledge including semantics, syntax, and rules about how morphological components are manipulated to derive meaning (Zhang et al., 2020; Levesque et al., 2021). Mid-elementary school (around age 8–9) may be a point in development where there is a change from primary involvement of morphological awareness in reading comprehension gains in early childhood to relying primarily on morphological analysis in the acquisition of more advanced reading comprehension skills. However, these predictions are largely untested in the literature. Research is required to better understand the contribution of morphological analysis to reading comprehension cross-sectionally and longitudinally in younger ages when children are developing reading skills.

The present study

This longitudinal study builds upon past cross-sectional research by examining how two aspects of morphological processing, awareness and analysis, contribute to reading comprehension throughout early elementary school, from Grades 1 to 3 (ages 6 to 9). Most of the research on the relationship between distinct aspects of morphological processing and reading comprehension focuses on children in mid- to late-elementary school years (e.g., Beyersmann et al., 2012; Levesque et al., 2017; Dawson et al., 2018). The present study examined this relationship at an earlier point in the developmental trajectory of reading comprehension acquisition, focusing on children's morphological awareness, morphological analysis, and reading comprehension longitudinally in five waves of testing from Grades 1 to 3.

Hypotheses and rationale

We add to the knowledge of the roles of morphological awareness and analysis on reading comprehension by focusing on developmental change during early reading acquisition. We explore the impact of morphological awareness and analysis on development of reading comprehension from a multidimensional lens in children ages 6–9 years. Conceptually, the links among awareness, analysis, and comprehension may change as children grow older, and these changes may be evident during early reading development. We assume that initial links involve morphological awareness as a skill that is established before morphological analysis; with further development, analysis is established and becomes an important influence on children's reading comprehension in the later waves of the age range studied. Most growth in morphological awareness occurs during the first three or four school years (Berninger et al., 2009) when children make concurrent gains in reading and vocabulary (Ramirez et al., 2014). In the first two school years, while children establish basic reading skills, the demands on reading comprehension are relatively light compared to the demands on reading comprehension in the third and fourth school years when texts that children encounter are more complex, and multimorphemic words appear more frequently in complex sentences. As reading becomes more fluid and curricular demands on children change from learning to read to reading to learn at about Grade 3, the morphological processing skills required for reading comprehension may change as well (Chall, 1983).

With strong morphological awareness skills, children may have the foundational understanding of morphemes necessary to enable a change to using morphological analysis to decipher and extract meaning from morphologically complex words through the words' smaller morphemic units (Levesque et al., 2017). This makes meaning extraction from complex text more efficient. At about Grade 3 morphological analysis may be particularly useful for advanced reading comprehension, when the increased frequency of morphologically complex words places greater demands on inferring meaning (Xie et al., 2019; Levesque et al., 2021).

Based on prior findings, we hypothesized that:

1. During Waves 1–3 (in Grades 1 and 2), morphological awareness would be a concurrent predictor of reading comprehension.
2. With stronger reading skills in Waves 4 and 5 (Grade 3), morphological analysis would be a concurrent predictor of reading comprehension. As frequency of morphologically complex words in reading materials increases, morphological analysis would be the predominant strategy to facilitate reading comprehension (Levesque et al., 2019, 2021).
3. Predictive relationships would change, showing morphological awareness predicts growth in reading comprehension between waves from Waves 1 to 4, and morphological analysis predicts growth in reading comprehension from Wave 4 to 5 (Levesque et al., 2019).

Method

Participants

Children in Grade 1 were recruited from 12 diverse (urban and suburban) elementary schools within three public school divisions in Winnipeg, Manitoba, Canada. The children participated at five testing occasions: spring of Grade 1, fall of Grade 2, spring of Grade 2, fall of Grade 3, and spring of Grade 3. Each testing period was separated by ∼6 months. Demographic information from the initial sample is listed in Table 1. The study began with 171 children in Grade 1 and by the final wave of testing 137 participants remained. The mean age of participants at Wave 1 was 81.00 months (6.75 years) and at the final wave it was 106.63 months (8.89 years). Prior

TABLE 1 Participant demographics at wave 1.

Demographics	Frequency (%)
N	171 (100)
Sex	
Male	94 (54.7)
Female	77 (44.8)
SES	
High	59 (34.3)
Middle	82 (47.7)
Low-middle	13 (7.6)
Low	17 (9.9)
Primary language spoken at home	
English	154 (90.0)
Other	17 (10.5)

SES, Socio-Economic Status based on neighborhood income levels.

TABLE 2 Numbers (and percentages) of children scoring more than one standard deviation below the population mean standard scores on word comprehension, passage comprehension or both at each testing wave.

Wave	WC N	WC < 1.0 SD	PC N	PC < 1.0 SD	Both < 1.0 SD	Total < 1.0 SD
1	171	1 (0.60)	171	21 (12.28)	11 (6.43)	33 (19.30)
2	157	4 (2.54)	149	5 (3.36)	11 (7.38)	20 (13.42)
3	155	6 (3.87)	151	8 (5.30)	12 (7.95)	26 (17.22)
4	141	4 (2.84)	141	8 (5.67)	15 (10.64)	27 (19.15)
5	137	2 (1.46)	134	4 (2.99)	9 (6.72)	15 (11.19)

Percentages in parentheses. WC N—number of WRMT Word Comprehension subtests completed at each wave of testing; PC N—number of WRMT Passage Comprehension subtests completed at each wave of testing. WC < 1 SD—number (and percentage) of participants scoring lower than 1.0 SD of the population mean standard score on the WC subtest only. PC < 1 SD—number (and percentage) of participants scoring lower than 1.0 SD of the population mean standard score on the PC subtest only. Both < 1.0 SD—number (and percentage) of participants scoring lower than 1.0 SD of the population mean standard score on each of WC and PC subtests. Total < 1.0 SD—tally of number of participants and percentage scoring lower than 1.0 SD below population mean on either or both subtests. Both and Total percentages were based on the smaller number of the two tests completed in waves in which different numbers of the two tests were completed.

to the first wave of data collection, participants' teachers were asked to nominate at-risk to average skilled readers, based on curriculum-based measures to ensure a wide range of initial reading abilities. Although we initially used a lenient criterion of scoring 0.5 SD or more below the population mean on our reading measures in Wave 1 to identify poor readers, this criterion is higher than typical diagnostic standard-score cut-offs (e.g., more than 1.0 SD below standard score population mean). Hence, we used a stricter more-diagnostic cut-off to identify poor readers. Table 2 provides the number and proportion of children in the sample at each wave who scored lower than 1.0 SD below the population mean on one or both subtests. The percentages are within the range expected based on a normal distribution of standard scores lower than 1.0 SD below the mean (16 percent) on each subtest. Hence, we believe that our sample is representative of the range and frequency of reading abilities in the general population. Parent/guardian consent was provided for each participant and children provided verbal assent before each testing occasion; ethical approval was provided by a university research ethics board.

English was the primary language spoken at home for 154 of the 171 participants in Wave 1 and 125 of the 137 participants left in Wave 5. Most parents who reported home languages other than English indicated that English was spoken at home in addition to the other home language. Eight reported that English was not spoken at home at Wave 1, and six in Wave 5. Five of these eight Wave 1 children scored lower than 1.0 SD below the Vocabulary subtest population mean T-score. Omitting these five from the analyses did not produce substantial differences in patterns compared to using the full sample, and so we decided to use the full sample to maintain adequate statistical power. We outline the potential implications of this decision in the Limitations.

Materials and procedure

This study used data from a larger longitudinal study examining sensory and language factors involved in reading acquisition in children. The measures of morphological awareness and analysis and reading comprehension were administered in quiet rooms at the children's schools, as part of a larger battery of measures in four 30-min sessions. Sessions for each participant took place on different days within a two-week time frame to minimize participant fatigue. Within sessions, the measures were administered in the same order and standard administration procedures were followed for standardized tests.

Morphological awareness

Morphological knowledge test

This task was a modified version of a task used by Carlisle and Fleming (2003) as a measure of morphological awareness involving derivational and inflectional knowledge (see Kruk and Bergman, 2013 for a full list of test items). In this task, participants are presented with a word followed by an incomplete sentence. Participants are then asked to complete the sentence by using the appropriate form of the word provided. The task is made up of 48 items. There are 24 "compose" items which require participants to produce larger multimorphemic words from root words (e.g., "enter," "He greeted me when I ___." [entered]) and 24 "decompose" items which require participants to produce root words from larger multimorphemic words (e.g., "cutting," "I got my hair ___." [cut]). The order of item sets was counterbalanced, and participants were provided with three practice items per set. To create a latent variable, two separate indicators were created by using the total raw score on participant performance on the compose items and on the decompose items. Internal reliabilities at Wave 1 were $\alpha = 0.78$ for the compose items and $\alpha = 0.82$ for the decompose items.

Morphological analysis

Absolute vocabulary knowledge test

This task is a modified version of a test used by Anglin (1993) as a measure of participants' morphological analysis ability by requiring children to infer the meaning of morphologically complex and/or unfamiliar words. In this task, participants were orally presented with 10 low-frequency two-morpheme words (e.g., soaking, treelet), one at a time. For each item, children were asked to first define the word and then to construct sentences that demonstrate the word's correct meaning. Participants were given an accuracy score for their definition of each of the 10 items, including a combination of root and suffix meanings, and a second score for their ability to use the item in a meaningful sentence for a maximum of 20 points total. The item difficulty was not determined prior to administration and therefore the items were not rank ordered based on determining characteristics. To create a latent variable of morphological analysis, three separate indicator scores were created. The three groups of indicator items were created based on the order items were presented to participants with every third item score distributed into a different group (see Appendix 1 for a list of test items). This was done to ensure a relatively equal number of definition and sentence scores were distributed in each group. Internal reliability at Wave 1 for the test items was 0.63. Reliability for the three indicator variables created was $\alpha = 0.70$.

Reading comprehension

Woodcock reading mastery test-revised

The Woodcock Reading Mastery Test-revised (WRMT-R) is a diagnostic test that assesses several reading abilities (Woodcock, 1998). To measure participant reading comprehension, two subtests of the WRMT-R were used.

The Word Comprehension subtest measured children's comprehension of increasingly complex words (Woodcock, 1998). Participants were asked to provide synonyms and antonyms for words, and to provide appropriate words for increasingly difficult analogies for up to 146 items (up to 33 synonyms, 34 antonyms, and 79 analogies). The test was discontinued after six consecutive errors on each of the synonyms, antonyms, and analogies sets.

The Passage Comprehension subtest measured children's comprehension of continuous text (Woodcock, 1998). Participants were presented with up to 68 passages, each with a missing word. They read each passage silently and then provided a suitable word to fill in the blank. The test was discontinued after six consecutive errors. Total scores from the Word Comprehension and Passage Comprehension subtests were used in the analysis as separate indicators for the latent variable of reading comprehension. Raw scores were used to maintain information on developmental change. Split-half reliabilities based on the normative sample for the ages of participants ranged from 0.91 to 0.95 for word comprehension, and from 0.92 to 0.94 for passage comprehension (Woodcock, 1998).

Control and auxiliary measures

Wechsler abbreviated scale of intelligence

Participant performance on the Vocabulary and Matrix Reasoning subtests of the Wechsler Abbreviated Scale of Intelligence (WASI) were used to measure participants' non-verbal and verbal intelligence (Wechsler, 1999). The Vocabulary subtest includes four picture items and 38 word items. Participants were instructed to name the objects shown in the pictures for the first four items and to provide a definition for each subsequent word item. The Matrix Reasoning subtest required participants to complete a visual puzzle in the form of a matrix with one missing section. Participants had to choose an image that best fit the missing section from five response options. The WASI subtests were used to ensure participants had the cognitive functioning necessary to understand instructions and participate in the measures. An IQ estimate was derived from a composite of both subtests and participants with standard scores below 75 were to be excluded; however, no participants met this exclusionary criterion. Internal consistency reliabilities for the subtests ranged from 0.86 to 0.92 across the ages involved in the study (Wechsler, 1999).

Comprehensive test of phonological processing

Participant performance on the Elision subtest of The Comprehensive Test of Phonological Processing (Wagner et al., 1999) was used as a measure of phonological awareness. The Elision subtest consists of 20 items. Participants were required to repeat a target word aloud and then repeat it with specific phonemes omitted (e.g., "bold," without saying /b/). Split-half reliabilities ranged from 0.89 to 0.92 across the ages of participants (Wagner et al., 1999).

Data analysis

Overview

Statistical analyses were completed using IBM SPSS version 27 and MPlus version 8.7. A 5-wave Cross Lagged Panel Analysis using Full Information Maximum Likelihood Estimation (FIML) allowed us to examine the predictive and concurrent relationships among the constructs of morphological awareness, morphological analysis, and reading comprehension. Each construct was specified as a latent variable at each of the five waves. Two indicators of reading comprehension, two indicators of morphological awareness, and three indicators of morphological analysis were used to create latent variables (as described above). Both first-order autoregressive effects and cross-lagged effects were included in the models and correlations among the residuals of the same constructs across the five waves of testing were included to consider the covariance among the residuals (Marsh et al., 1999).

Modeling statistics were examined to evaluate model fit. These included measures of absolute fit, the Root Mean Square Error of Approximation (RMSEA) and the Standardized Root Mean Square Residual (SRMR), and a measure of relative fit, the Comparative Fit Index (CFI); all were considered when evaluating model fit. The cut-off values indicating good fit are: RMSEA $\leq$ 0.06, SRMR $\leq$ 0.08, and CFI $\geq$ 0.95 (Kline, 2016; Zhang et al., 2019). Competing models were created by systematically altering pathways based on statistical fit and considering theoretical rationale, starting with a fully specified model that included concurrent and predictive links among all latent traits, and then eliminating non-significant links to achieve best model fit. Relative model fit was evaluated using the chi-square difference test ($\Delta\chi^2$), which compares the difference between models' χ^2 statistics, and change in the CFI value (ΔCFI) was used while also examining change in the fit statistics described above (Cheung and Rensvold, 2002). A $\Delta\chi^2$ test p-value of $\leq$0.05 and/or a ΔCFI difference of 0.01 indicates that there is a significant difference between models (Cheung and Rensvold, 2002).

10.3389/flang.2024.1367637

TABLE 3 Means and, standard errors for raw total correct measures of reading comprehension, morphological awareness, and morphological analysis of children scoring lower than and children scoring at-and-higher than 1.0 SD below population mean on one or more reading comprehension measures across waves.

Variable	Wave 1		Wave 2		Wave 3		Wave 4		Wave 5	
	Lower *M* (SE)	Higher *M* (SE)	Lower *M* (SE)	Higher *M* (SE)	Lower *M* (SE)	Higher *M* (SE)	Lower *M* (SE)	Higher *M* (SE)	Lower *M* (SE)	Higher *M* (SE)
WC	0.64 (0.14)	10.83 (0.90)	2.75 (0.69)	21.08 (1.04)	9.04 (1.20)	27.85 (0.97)	14.33 (1.63)	35.85 (0.89)	16.93 (2.10)	37.92 (0.88)
PC	0.52 (0.14)	12.67 (0.70)	5.60 (1.24)	20.27 (0.72)	9.81 (1.67)	24.63 (0.71)	14.44 (1.11)	30.32 (0.57)	16.13 (1.82)	31.74 (0.50)
MKT	21.55 (1.11)	28.83 (0.54)	27.11 (1.41)	33.28 (0.49)	28.50 (1.74)	36.10 (0.45)	34.60 (1.04)	40.06 (0.38)	36.50 (1.39)	40.83 (0.36)
AVKT	1.27 (0.20)	3.07 (0.18)	2.32 (0.51)	3.31 *ns* (0.21)	2.56 (0.52)	4.16* (0.28)	3.26 (0.42)	6.00 (0.28)	4.93 (0.65)	7.51** (0.32)

Lower = participants scoring lower than 1.0 SD below population mean standard score on one or both of the reading comprehension measures; Higher = participants scoring at or higher than 1.0 SD below population mean on both reading comprehension measures.
WC, Word Comprehension subtest (Woodcock Reading Mastery Test-Revised); PC, passage comprehension subtest (Woodcock Reading Mastery Test-Revised); MKT, Morphological Knowledge Test; AVKT, Absolute Vocabulary Knowledge Test.
All group comparisons within waves $p < 0.001$, using independent-groups t-tests, except as indicated, $^{*}p < 0.05$, $^{**}p < 0.01$, ns, not significant.

TABLE 4 Means and, standard deviations for raw measures of reading comprehension, morphological awareness, and morphological analysis across waves.

Variable	Wave 1		Wave 2		Wave 3		Wave 4		Wave 5	
	N	Mean (SD)	*N*	Mean (SD)	*N*	Mean (SD)	*N*	Mean (SD)	*N*	Mean (SD)
WC	171	8.87 (10.28)	157	18.60 (12.67)	155	24.70 (12.94)	141	31.73 (12.59)	137	35.62 (11.58)
PC	171	10.33 (8.81)	149	18.30 (9.33)	151	22.08 (9.75)	141	27.28 (8.71)	134	30.00 (7.48)
MKT	171	27.42 (6.92)	149	32.46 (5.99)	152	34.80 (6.49)	137	39.07 (4.76)	135	40.38 (4.31)
AVKT	171	2.73 (2.12)	151	3.21 (2.43)	153	3.90 (3.14)	139	5.45 (3.00)	133	7.23 (3.43)

WC, word comprehension (Woodcock Reading Mastery Test-revised); PC, passage comprehension (Woodcock Reading Mastery Test-Revised); MKT, Morphological Knowledge Test; AVKT, Absolute Vocabulary Knowledge Test.

Missing data analysis

Thirty-six participants were lost due to attrition by the final wave of testing, primarily because children moved schools or were absent on testing days; partial data from participants' missing sessions were included. Missing data were tested for differences between participants with complete data and with incomplete data on morphology and comprehension measures to determine if data were missing at random or not missing at random (Enders, 2010). Little's MCAR test, involving all indicator variables across all waves, was not significant [$\chi^2_{(670)} = 660.03$, $p = 0.601$], showing that the missing data can be considered missing at random, and that other auxiliary variables could account for any systematic patterns of missingness (Nicholson et al., 2017). Independent samples t-tests comparing initial-wave scores of participants with data missing at the final wave ($n = 36$) to those without missing data ($n = 135$) showed significant differences on all indicator variables, except for one of the indicators of morphological analysis. The missing-data group performed worse on all variables with significant differences: word comprehension [$t_{(169)} = 3.29$, $p = 0.001$], passage comprehension [$t_{(169)} = 3.07$, $p = 0.002$], the Morphological Knowledge Test indicators of morphological awareness [$t_{(168)} = 3.17$, $p < 0.001$] and [$t_{(169)} = 3.78$, $p < 0.001$] for compose and decompose respectively, and the Absolute Vocabulary Knowledge test indicator 1 [$t_{(169)} = 2.86$, $p = 0.002$] and indicator 3 [$t_{(169)} = 3.67$, $p < 0.001$] as measures of analysis. This shows the attrition-group data are not missing completely at random (MCAR).

In addition to using FIML to manage the systematic differences between the attrition and non-attrition groups, Elision ($M = 7.39$, $SD = 4.22$) and Vocabulary ($M = 20.33$, $SD = 5.72$) subtest raw scores at the first wave were added to the models as auxiliary variables to approximate the MAR pattern (Collins et al., 2001; Enders, 2010; Nicholson et al., 2017). Elision and Vocabulary have established relationships with morphological abilities and reading comprehension (Hogan et al., 2005; Nation et al., 2007) and were both significantly correlated with all outcome measures at Wave 1 (p's < 0.01; see Table 5). Univariate ACNOVAs on initial-wave factors showed that Elision and Vocabulary together eliminated the statistical differences found between the attrition and non-attrition groups.

Results

Descriptive statistics

Descriptive statistics for scores on measures of reading comprehension, morphological awareness, and morphological analysis at each wave for the group scoring lower than 1.0 SD below the population mean standard score on one or more of the reading comprehension measures (Lower), and in the group scoring higher than 1.0 SD below the population mean (Higher) are reported in Table 3. The Lower group scored worse than the Higher group on all measures at each wave, except the AVKT in Wave 2. Comparable statistics for the complete sample are given in Table 4. Patterns of relative growth are indicated across the five waves of testing for each measure, overall and for both reading-ability groups. Tables 5–9 give correlations among indicator variables for each wave of testing—all coefficients were significant and positive.

Cross-lagged panel models

A series of cross-lagged panel analysis models were used to test the hypotheses and examine the relationship among the latent variables of morphological awareness, morphological analysis, and reading comprehension across this early developmental period in reading comprehension acquisition. Autoregressive links for each of the latent variables were included throughout the five testing waves to account for prior level of skill and to explore the temporal stability in these variables, with larger coefficients indicating greater stability (Kearney, 2017). Inclusion of the two covariates identified in the missing data analysis, phonological awareness and vocabulary, were entered in all models as auxiliary variables.

Initial model: autoregressive

An initial model that included all autoregressive paths among the latent variables was tested to explore the presence of stability in reading comprehension, morphological awareness, and morphological analysis across the five waves of testing. As seen in Figure 1, all 12 autoregressive paths were statistically significant as expected, indicating stability over time for each of the latent variables. Figure 1 also displays the coefficients for each indicator associated with the latent variables. The measurement model showed that all indicator variables were appropriate for the latent variables and statistically significant at $p < 0.001$. Although all the autoregressive paths were significant, this model did not produce a good fit: $\chi^2_{(542)} = 891.234$, $p < 0.001$, RMSEA $= 0.061$, CFI $= 0.928$, SRMR $= 0.106$. Since this model provided an inadequate fit of the data, we examined the potential improvements in model fit with the addition of predictive and concurrent links, starting with the fully specified model, and then followed by models that eliminated non-significant links while allowing us to test our hypotheses.

Fully specified model

Given our primary focus on morphological processes in children's growth in reading comprehension, we explored the fully specified model that included links reflecting the influences of morphological analysis and morphological awareness on reading comprehension predictively and concurrently. In this model, the 12 autoregressive links were retained from the initial model. To examine predictive relationships, we included eight cross-lagged predictive pathways between testing waves from awareness and analysis to the subsequent reading comprehension wave, and 15 concurrent links were entered, involving the three latent variables within each wave. Cross-lagged predictive links involving morphological awareness and morphological analysis between waves were initially entered as well; however, this larger model did not converge due to too many free parameters for the available observations. Therefore, these pathways were entered one at a time, as indicated by our hypotheses. We expected significant concurrent links between awareness and comprehension in the first four waves, and between analysis and comprehension in the final wave.

TABLE 5 Correlations among indicators of latent variables and auxiliary variables at wave 1.

	Vocab	Elr	WC	PC	AVKT_1	AVKT_2	AVKT_3	MKT CO	MKT DC
Vocab	–								
Elr	0.375**	–							
WC	0.329**	0.738**	–						
PC	0.349**	0.733**	0.909**	–					
AVKT_1	0.431**	0.554**	0.517**	0.490**	–				
AVKT_2	0.356**	0.420**	0.374**	0.370**	0.428**	–			
AVKT_3	0.411**	0.441**	0.399**	0.424**	0.448**	0.450**	–		
MKT CO	0.432**	0.532**	0.583**	0.583**	0.506**	0.358**	0.438**	–	
MKT DC	0.435**	0.507**	0.532**	0.543**	0.440**	0.322**	0.355**	0.649**	–

Vocab, vocabulary subtest of the WASI; Elr, phonological awareness (Elision subtest); WC, word comprehension subtest of the WRMT-R; PC, passage comprehension subtest of the WRMT-R; AVKT, Absolute Vocabulary Knowledge test (indicator 1, 2, and 3); MKT CO, Morphological Knowledge Test composed items raw score; MKT DC, Morphological Knowledge Test decomposed items raw score.
**$p < 0.01$.

TABLE 6 Correlations among indicators of latent variables at wave 2.

	WC	PC	AVKT_1	AVKT_2	AVKT_3	MKT CO	MKT DC
WC	–						
PC	0.919**	–					
AVKT_1	0.530**	0.439**	–				
AVKT_2	0.391**	0.349**	0.556**	–			
AVKT_3	0.381**	0.357**	0.422**	0.476**	–		
MKT CO	0.595**	0.603**	0.401**	0.418**	0.433**	–	
MKT DC	0.506**	0.542**	0.332**	0.242**	0.310**	0.590**	–

WC, word comprehension subtest of the WRMT-R; PC, passage comprehension subtest of the WRMT-R; AVKT, Absolute Vocabulary Knowledge test (indicator 1, 2, and 3); MKT CO, Morphological Knowledge Test composed items raw score; MKT DC, Morphological Knowledge Test decomposed items raw score.
**$p < 0.01$.

TABLE 7 Correlations among indicators of latent variables at wave 3.

	WC	PC	AVKT_1	AVKT_2	AVKT_3	MKT CO	MKT DC
WC	–						
PC	0.889**	–					
AVKT_1	0.643**	0.535**	–				
AVKT_2	0.569**	0.521**	0.707**	–			
AVKT_3	0.539**	0.454**	0.615**	0.647**	–		
MKT CO	0.739**	0.683**	0.570**	0.539**	0.485**	–	
MKT DC	0.618**	0.597**	0.421**	0.406**	0.400**	0.660**	–

WC, Word Comprehension subtest of the WRMT-R; PC, passage comprehension subtest of the WRMT-R; AVKT, Absolute Vocabulary Knowledge test (indicator 1, 2, and 3); MKT CO, Morphological Knowledge Test composed items raw score; MKT DC, Morphological Knowledge Test decomposed items raw score.
**$p < 0.01$.

Predictive links were expected to be significant from awareness to comprehension between waves from Waves 1 through 4, and from analysis to comprehension between Waves 4 and 5. Additional concurrent and predictive links between awareness, analysis, and comprehension were explored, especially predictive links from awareness as an earlier-acquired skill to next-wave analysis.

Significant links were retained in the final model, shown in Figure 2 (non-significant links are not shown for clarity). All autoregressive links were significant at $p < 0.001$. Four cross-lagged predictive links involving reading comprehension were significant, involving awareness to subsequent reading comprehension from Wave 1 to Wave 2, from Wave 2 to Wave 3, and from Wave 4 to Wave 5. A significant negative coefficient was found for the path from analysis at Wave 4 to reading comprehension at Wave 5. Significant concurrent links were found among all three latent variables at Waves 1 and 2 and there were significant concurrent

TABLE 8 Correlations among indicators of latent variables at wave 4.

	WC	PC	AVKT_1	AVKT_2	AVKT_3	MKT CO	MKT DC
WC	–						
PC	0.868**	–					
AVKT_1	0.536**	0.497**	–				
AVKT_2	0.473**	0.408**	0.521**	–			
AVKT_3	0.535**	0.428**	0.541**	0.616**	–		
MKT CO	0.700**	0.613**	0.541**	0.440**	0.414**	–	
MKT DC	0.554**	0.477**	0.425**	0.330**	0.386**	0.616**	–

WC, Word Comprehension subtest of the WRMT-R; PC, passage comprehension subtest of the WRMT-R; AVKT, Absolute Vocabulary Knowledge test (indicator 1, 2, and 3); MKT CO, Morphological Knowledge Test composed items raw score; MKT DC, Morphological Knowledge Test decomposed items raw score.
**p < 0.01.

TABLE 9 Correlations among indicators of latent variables at wave 5.

	WC	PC	AVKT_1	AVKT_2	AVKT_3	MKT CO	MKT DC
WC	–						
PC	0.877**	–					
AVKT_1	0.497**	0.426**	–				
AVKT_2	0.422**	0.359**	0.611**	–			
AVKT_3	0.498**	0.409**	0.543**	0.697**	–		
MKT CO	0.629**	0.552**	0.452**	0.381**	0.438**	–	
MKT DC	0.373**	0.298**	0.273**	0.300**	0.174*	0.412**	–

WC, Word Comprehension subtest of the WRMT-R; PC, passage comprehension subtest of the WRMT-R; AVKT, Absolute Vocabulary Knowledge test (indicator 1, 2, and 3); MKT CO, Morphological Knowledge Test composed items raw score; MKT DC, Morphological Knowledge Test decomposed items raw score.
*p < 0.05.
** p < 0.01.

links between analysis and reading comprehension at Waves 3 and 5. When entered individually, all cross-lagged links from awareness to subsequent waves of analysis and from analysis to subsequent waves of awareness were not significant except for a significant link from Wave 3 awareness to Wave 4 analysis. Model fit statistics were: $\chi^2_{(524)} = 783.722$, $p < 0.001$, RMSEA $= 0.054$, CFI $= 0.946$, SRMR $= 0.064$. Most fit statistics indicated good fit and the CFI was close to the specified threshold. Compared to the initial model, adding predictive and concurrent links improved the fit as indicated in a statistically significant $\Delta\chi^2$ test result ($\Delta\chi^2 = 107.51$, $df = 18$) and a ΔCFI of 0.018. These indicate that predictive and concurrent paths can clarify the relationship among the latent variables.

The pattern of concurrent and predictive links partially supported our hypotheses about the influences of awareness and analysis on reading comprehension: (1) Awareness to comprehension concurrent links were significant at the first two waves only, indicating that this early involvement of awareness concurrently in reading comprehension is relatively short-lived. (2) Analysis to comprehension concurrent links were significant at all waves except Wave 4. This indicates that analysis is an important and unique concurrent indicator of reading comprehension when reading comprehension skills are not well developed, and that more-complex morphological skills play roles in reading comprehension earlier than expected. The importance of analysis to later reading comprehension is evident in the significant concurrent link in the final wave, as expected. (3) Awareness predicted subsequent reading comprehension between waves, including between Waves 4 and 5, but not between Waves 3 and 4—here the predictive link between awareness and analysis was significant. Morphological analysis did not predict reading comprehension between waves, except for between Waves 4 and 5 where it was expected—however the coefficient unexpectedly was negative.

Discussion

We examined the relationships among morphological awareness, morphological analysis, and reading comprehension from Grade 1 to 3 (ages 6–9 years). Morphological awareness, conceptualized as knowledge of and ability to manipulate morphemes, was contrasted with morphological analysis, the use of morphological information to infer the meaning of unfamiliar or morphologically complex words (Baumann et al., 2002; Carlisle, 2007; Kirby et al., 2012; Levesque et al., 2019). This research extends previous literature by providing a cross-lagged multiple-wave longitudinal design that examines the developmental trajectory of distinct morphological processes and reading comprehension and the relationships among them during a period of early reading acquisition.

We hypothesized a change in the contributions of morphological awareness and analysis to reading comprehension

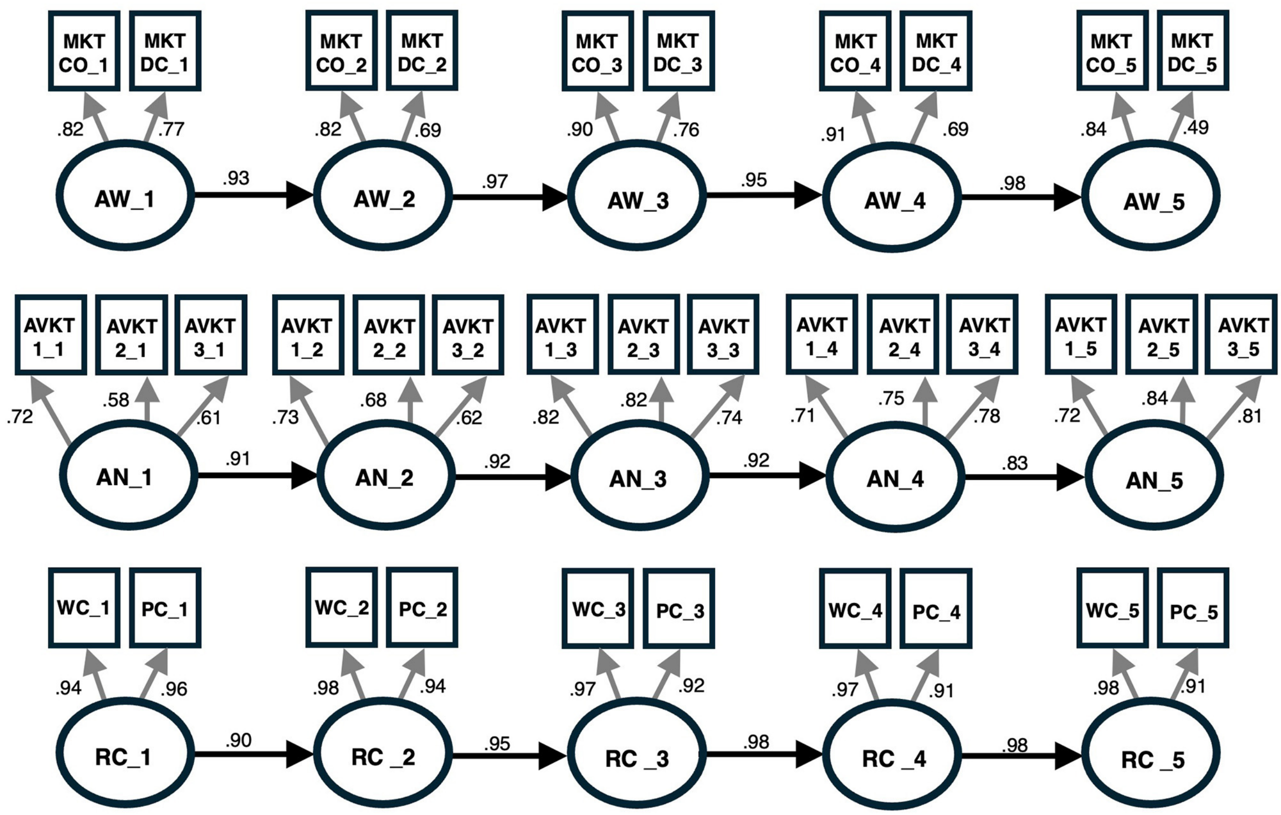

FIGURE 1
Initial model: autoregressive paths and latent variable indicators. Wave number is indicated by the digit at the end of each variable name. AW, morphological awareness; AN, morphological analysis; RC, reading comprehension; MKT CO, Morphological Knowledge Test compose; MKT DC, Morphological Knowledge Test decompose; AVKT, Absolute Vocabulary Knowledge test; WC, word comprehension; PC, passage comprehension. Values represent standardized coefficients. All coefficients are significant at $p < 0.001$.

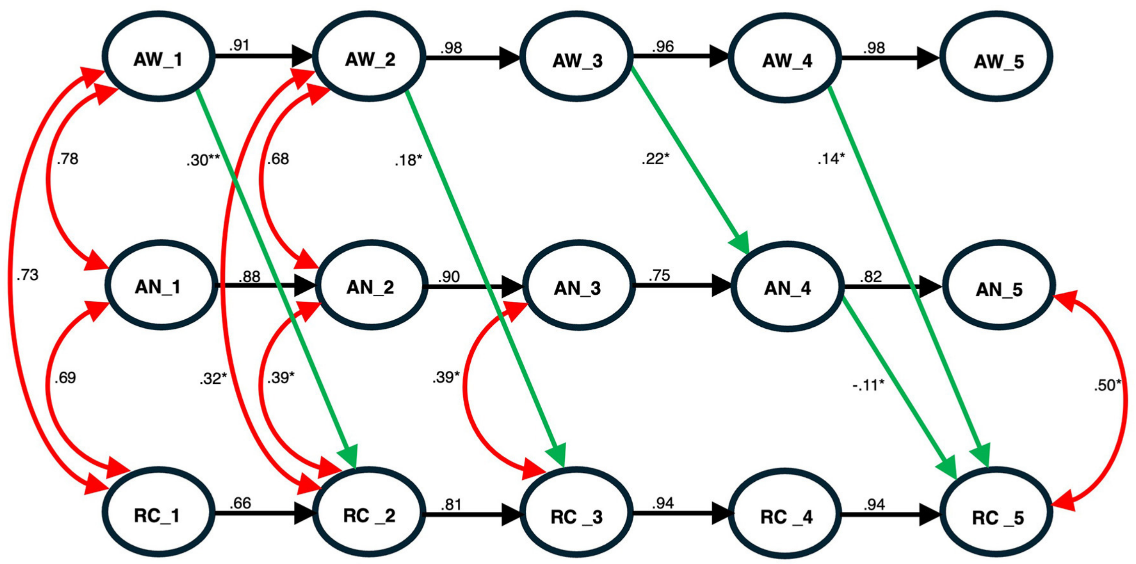

FIGURE 2
Final cross lagged panel model. Wave number is indicated by the digit at the end of each variable name. AW, morphological awareness; AN, morphological analysis; RC, reading comprehension. Values represent standardized coefficients. For sake of model clarity, latent variable indicators, auxiliary variables, and insignificant links are omitted from the figure. All coefficients are significant at $p < 0.001$, except as indicated; *$p < 0.05$; **$p < 0.01$.

from Grade 1 to Grade 3. We expected that in the early part of this period, in Waves 1–3, morphological awareness would play a prominent concurrent role in reading comprehension. Morphological analysis would play a prominent concurrent role in later reading comprehension in Grade 3 (Waves 4 and 5) when children encounter more morphologically complex words. This would signify a change in strategy use from morphological awareness to analysis to facilitate reading comprehension (Levesque et al., 2019). Significant predictive relationships were hypothesized to include the links between morphological awareness to subsequent reading comprehension across Waves 1–4 (Grade 1 to the beginning of Grade 3), and that analysis would predict growth in reading comprehension from Waves 4 to 5 (the end of Grade 3). Predictive relationships from awareness to analysis and analysis to awareness were also explored.

To examine these relationships, autoregressive, concurrent, and predictive pathways between morphological awareness, analysis, and reading comprehension were included in cross-lagged panel modeling. All potential relationships across waves were examined. The results partially supported the hypothesized model, as summarized above. As expected, all autoregressive pathways were significant for each of the three outcome variables signifying stability in the growth of morphological processes and reading comprehension throughout this period with past skills predicting future skills (Kline, 2016). Autoregressive pathways allowed for greater confidence in the additional significant relationships that were found as these relationships maintained their significance even after accounting for prior level of ability (Kearney, 2017).

Morphological awareness was a significant predictor of early reading comprehension growth; these early predictive associations reflect the role of morphological awareness early in the development of reading comprehension skills (Deacon et al., 2018; James et al., 2021). The later predictive relationship between morphological awareness and reading comprehension, from Waves 4–5 (the end of Grade 3) indicates that the influential role of morphological awareness on reading comprehension is maintained even for more-mature comprehension skills at the oldest age studied. Morphological awareness was a concurrent predictor of reading comprehension in Waves 1 and 2, suggesting a bidirectional influence of early morphological awareness and reading comprehension skills, in addition to the predictive role of morphological awareness. These findings are consistent with previous research showing morphological awareness to be a significant contributor to reading comprehension over time (Foorman et al., 2012; Kirby et al., 2012; Kruk and Bergman, 2013; Deacon et al., 2014; Levesque et al., 2017). This supports the idea that morphological awareness concurrently enhances early-years reading comprehension as children practice both morphological and reading-related skills. However, the unexpected concurrent links between morphological analysis and reading comprehension in the first two waves indicate that children have the capacity to apply morphological analysis skills to facilitate reading comprehension. However the roles that analysis likely plays in facilitating reading comprehension skills in young children are likely different from the roles played in the later wave, as would be predicted by the morphological pathways framework. Although morphological analysis does not predict subsequent reading comprehension at any point other than the final wave, the late concurrent link, involving stronger morphological understanding, may involve children using strategic morphological analysis skills to meet increasingly demanding reading comprehension experiences at Wave 5. This finding is consistent with research showing that while morphological awareness contributes directly and indirectly to reading comprehension, morphological analysis contributes primarily in indirect ways (Levesque et al., 2017; Goodwin et al., 2020; Zhang et al., 2020).

Morphological analysis may play a particularly useful concurrent role in later reading comprehension. As children are exposed to increasingly morphological complex words with greater demands to infer meaning, these demands may require indirect mediation through lexical access and processing of semantic, morphological, and syntactic aspects of lexical representations to facilitate reading comprehension (Nagy and Anderson, 1984; Nagy et al., 2006; Xie et al., 2019; Levesque et al., 2021). This concurrent reliance on analysis in comprehension may explain why the contribution of analysis to reading comprehension is not predictive at earlier points. During the earlier waves (1 through 3), analysis could facilitate reading comprehension through supporting practice and application of recently acquired strategies to parse and integrate morphological information in relatively simple words to evoke meaning in less-demanding reading comprehension tasks.

The significant predictive relationship from Wave 4 morphological analysis to Wave 5 reading comprehension was unexpected, given its negative relationship: strong prior morphological analysis skills predicted poorer reading comprehension skills. This may be the result of subtle changes in the development of processes underlying analysis and comprehension at that point in reading development. However, such a negative relationship would not be expected until later years. Goodwin et al. (2020) found Grade 8 children with limited reading vocabulary were unable to effectively apply strong morphological analysis skills to reading comprehension tasks. However, a more parsimonious explanation is that the negative predictive relationship is an epiphenomenon resulting from the concurrent positive influence of Wave 5 morphological analysis combined with the strong positive predictive influence of Wave 4 morphological awareness on Wave 5 reading comprehension. Replication of this negative pattern is needed for further interpretation, particularly on the impact of vocabulary abilities in use of morphological analysis for growth in reading comprehension.

The absence of concurrent or predictive influences of awareness and analysis on reading comprehension in Wave 4 was unexpected. This reduced influence of morphological awareness could be a consequence of the predictive paths from awareness in Wave 3 to analysis in Wave 4. The predictive link from awareness in Wave 4 to reading comprehension in Wave 5, in this context, indicates that although awareness continues to maintain a predictive role in reading comprehension growth additional changes are occurring in the roles of awareness and analysis in the latter two waves. This is consistent with our expectation that morphological analysis and reading comprehension become more closely related as children's language and reading comprehension skills grow. This is supported by Zhang et al. (2020), who found that morphological analysis mediates morphological awareness for students in Grade 4 and

5, particularly for those with strong English proficiency, and by findings indicating the importance of improved vocabulary in using morphological analysis for reading comprehension (Nakamoto et al., 2007). As young children develop stronger language and vocabulary skills, they may become better equipped to use indirect processes involving morphological analysis to support more-demanding reading comprehension tasks. The continued role of awareness in predicting reading comprehension at Wave 5 builds on previous findings of morphemic awareness facilitating reading comprehension in younger children (e.g., Deacon et al., 2018). We demonstrated concurrent influences of awareness on reading comprehension in Waves 1 and 2, and concurrent influences of analysis on reading comprehension that persists beyond Wave 2. Awareness continues primarily as a predictive influence on growth in reading comprehension across all waves but Wave 3. We interpret the strong positive relationships between Wave 4 awareness and Wave 5 reading comprehension and concurrent positive relationship between analysis and comprehension in Wave 5 as indicators of the changes we described in the roles of the two morphological processes with more-skilled reading comprehension.

Consistent with the literature on the relationships among morphological awareness, analysis and reading comprehension, our findings indicate that the relationships among these abilities change as children grow, particularly during the years of early literacy learning. As readers gain morphological knowledge and skills in morphological processing, and become increasingly familiar with morphological consistencies, morphological awareness and analysis may be useful at different points in their development to support reading and comprehending of novel and complex text—with awareness being more-prominent for very young children beginning to use reading comprehension skills, and analysis maintaining prominence even when reading comprehension skills are better established. The present study contributes to the literature by demonstrating that, in addition to phonological awareness, morphological awareness and analysis are important to children's reading comprehension in very young ages, but that their contributions to reading comprehension change as children's reading comprehension skills improve. Our comparisons between children who struggle and those who do not struggle with reading comprehension across the waves (Table 3) showed consistent group differences in awareness, analysis, word comprehension and passage comprehension, despite evidence of growth for both groups across waves (between wave comparisons of each indicator were significant for each group, all $ps < 0.001$). These consistencies indicate that from the first to the last wave poor morphological skills continue to be experienced in tandem with poor reading comprehension, despite growth in skills.

Identifying how anomalies associated with distinct aspects of morphological processing contribute to acquiring reading comprehension skills will help guide the design of educational practices and indicate when children are likely to benefit from morphological awareness and analysis instruction or intervention to support reading comprehension (Bowers et al., 2010; Nagy et al., 2014). Interventions and lessons focusing on identifying and manipulating the morphological structure of words may be more beneficial in the earlier grades to support later reading comprehension (Wolter et al., 2014; Good et al., 2015; Wolter and Gibson, 2015) and instruction focusing on teaching students to decipher meaning from unfamiliar morphologically complex words by strengthening their understanding of meanings associated with morphemes could continue to be beneficial in later grades (McCutchen et al., 2014; Crosson and McKeown, 2016; Zhang et al., 2020; Crosson et al., 2021).

Limitations and future directions

While the results of this study further our understanding of early development of children's morphological processing skills and reading comprehension, the study focused only on children learning to read in English. The developmental relationship between morphological awareness and morphological analysis may differ for languages with morphological and orthographic structures that are different from those of English. Although the patterns were identified in a diverse sample spanning a wide range of reading comprehension skills, a definitive conclusion that these patterns apply to both reading-disorder and typical reading development needs additional confirmation with comparisons between larger groups of reading-disordered and typical reading children.

The present study did not exclude participants whose home language was a language other than English, which is an important consideration for future research. Because most children in the sample, including three of the eight children whose parents reported no English use in the home in Wave 1, were proficient English speakers at the start of the study (the other five of the no-English-at-home children scored below 1.0 SD of the population mean on the vocabulary measure) the degree of negative influences of phonotactics from children's other languages on already established and subsequent English morphological awareness is likely small. Nevertheless, we recognize that long-term influences of additional languages can persist within additional-language processes, even in languages in which children are proficient. The research on initial language phonotactics influencing morpheme segmentation in a new language indicates strongest effects in adults who have lower proficiency in the new language, and who are learning a new language or engaging in statistical learning of a novel artificial language (e.g., Finn and Hudson Kam, 2015; Freeman and Marian, 2022). Hence, including children without English spoken at home or as a primary home language could have influenced our results, for example by suppressing the strength of the coefficients showing concurrent and predictive roles of awareness and analysis on children's reading comprehension. Despite our finding of no change in major patterns when the five low-vocabulary children who did not have English as a home language were not included in the analysis, future research endeavors could address this issue by examining explicitly patterns of growth in reading comprehension in children with English as an additional language.

The study of roles of components of morphological processing like awareness and analysis is relatively new, with varied conceptual and operational definitions (Zhang et al., 2020). Our conclusions reflect our conceptualizations and measurement methods for awareness, analysis and reading comprehension that reflect some but not all available methods to measure these constructs. For example, using the Absolute Vocabulary Knowledge Test (AVKT) to measure morphological analysis, though valid, might not have been the most-sensitive way to measure this ability in very young children. This method required children to produce definitions and sentences to orally provided morphologically complex words; previous research on morphological analysis has used receptive measures, involving children choosing the best response from several presented options, or by presenting morphologically complex words in sentence contexts, which place different, lighter, demands on participants (Goodwin et al., 2020; Zhang et al., 2020). Participants in the present study were highly challenged by the AVKT across waves. Hence, morphological analysis as reflected in our task is not highly developed even in the last wave, perhaps indicating that the expressive language demands of the task were too great for these students. Hence, different concurrent and predictive patterns might have been identified if a less-demanding measure of morphological analysis were used. Examining other ways in which morphological information and processes influence reading comprehension and its development in children would add to our understanding of the roles that morphological processes play in reading comprehension. For example, systematically manipulating morphological processes of complex words embedded in sentences that contain surrounding words that share structural features involving phonological, orthographic, semantic, morphological, or syntactic information might moderate morphological analysis and awareness and show more-nuanced effects on reading comprehension and growth in reading comprehension. These additional influences in tasks and measures could reflect more about roles of morphological processes beyond analysis and awareness, including potential memory savings from recent activation of shared morphemic components in other words in sentences, syntactic awareness and broad semantic understanding of gist and inferences contained in sentences and passages, among other language-related information and processes. Morphological processes involved in inferencing and in managing syntactic information, for example, could facilitate accurate selection of grammatical morphemes, and promote efficient morphological decoding.

Additional avenues for further research include extending the timeframe of the current study beyond Grade 3 to establish how the concurrent and predictive relationships, including in addition morphological decoding, continue to develop. Specific mediation analyses, for example involving strengths in morphological analysis in the presence of weaker vocabulary, would also be beneficial (Deacon et al., 2017; Zhang et al., 2020). These investigations could further our understanding of the relationship between morphological awareness, morphological analysis, and reading comprehension by demonstrating how the two aspects of morphological processing and reading comprehension influence one another when children have developed expertise in one or more of these domains. Additionally, this approach could be replicated in research that explicitly compares typical and struggling readers to explore the extent to which our assumption on the relevance of the relationships we identified across reading skills is valid. How children with different reading abilities use and access different morphological processes to support reading comprehension might change as their morphological and reading skills mature.

Conclusions

The present study identified longitudinal change in the roles of morphological awareness and analysis on reading comprehension in five waves from Grade 1 to Grade 3, beyond phonological awareness. While concurrent links among morphological awareness, analysis and reading comprehension were found in the first two waves, indicating earlier-than-expected involvement of analysis, significant predictive links of awareness were present for initial and later reading comprehension, consistent with previous research on older children in the elementary-school grades, but also illustrative of children's capacities in earlier years as novices in reading comprehension. As children became more skilled in reading comprehension by Grade 3, the concurrent role of analysis continued in Wave 5, and awareness dropped off as a concurrent influence, but with its predictive role for subsequent comprehension continuing between Waves 4 and 5.

Our findings point to the importance and distinct contributions of morphological awareness and analysis in children's acquisition of reading comprehension skill. These aspects of morphological processing influence one another concurrently in early elementary years, and predictive influences from awareness to reading comprehension and from awareness to analysis occur during the ages of children we investigated. The changes we identified in relations among morphological awareness, analysis, and reading comprehension indicate their dynamic nature during the early period of literacy learning, particularly as children's reading comprehension skills develop.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by University of Manitoba Research Ethics Board. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

KZ: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Methodology, Formal analysis, Conceptualization. RSK: Writing – review & editing, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Appendix

The absolute vocabulary knowledge test items.

1. Soaking
2. Changed
3. Reports
4. Forgotten
5. Enjoyable
6. Mucky
7. Stillness
8. Sourer
9. Knotless
10. Treelet