Unraveling Adolescent Language & Reading Comprehension: The Monster's Data

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by

Amanda P. Goodwin[1], Yaacov Petscher[2], & Dan Reynolds[3]

[1]Vanderbilt University's Peabody College, Nashville, TN
[2]Florida State University, Tallahassee, FL
[3]John Carroll University, University Heights, OH

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Abstract:

Purpose: This study explores the roles of morphological skills (Morphological Awareness, Morphological-Syntactic-Knowledge, Morphological-Semantic-Knowledge, and Morphological-Orthographic/Phonological-Knowledge), vocabulary (knowledge of definitions, relationships between words, and polysemous meanings), and syntax in contributing to adolescent reading comprehension. Specifically, we identify the relative importance of these language skills.

Methods: A racially diverse sample of 1,027 students grades 5 to 8 were studied. Dominance Analysis was used, which allows a rank ordering of the contribution of predictors.

Results: Results suggest unique roles for each language area with particularly important roles for vocabulary and morphological awareness. Considering just morphology, four morphology skills each explained meaningful variance (13-17%) in reading comprehension, together explaining half the variance in standardized reading comprehension. Considering each language area, vocabulary, the four morphology skills, and syntax were shown to each explain meaningful variance, ranging from 9-13%, together explaining 62.9% of the variance in reading comprehension.

Conclusions: Findings are interpreted within the Reading Systems framework. Findings confirm the role of vocabulary, morphology, and syntax in supporting reading comprehension and suggest a relatively stronger role for vocabulary and morphological awareness. The meaningful role of the four morphological skills also suggests a broad role for morphology. Implications for theory, research, and practice are shared.

Theory (Catts et al., 2006; Gough et al., 1996) and empirical evidence (Stanley et al., 2018) indicate language skills are foundational to reading comprehension. Across orthographies, by middle school, language skills are stronger predictors of reading comprehension than word reading skills (Catts et al., 2006; Florit & Cain, 2011; Gough et al., 1996). This likely reflects the increasing language demands of middle school texts (Hiebert et al., 2018; Nagy & Townsend, 2012) and limited unique role of word reading in reading comprehension (Foorman et al., 2015, 2018). Our study explores the relative importance of different language skills to reading comprehension to better inform understandings of this critical relation between language and reading comprehension.

Theory guides our exploration. In particular, Perfetti and Stafura's (2014) Reading Systems Framework argues that "word-to-text integration" (p. 30) involves "word comprehension" (p. 32) proceeding amongst multiple units: single word, phrasal, clause, sentence, and even across sentences. This goes beyond word identification or identifying a single word's meaning to include updating "the situation model [in a way] that integrates a word with a text representation" (p. 29) and continuing this updating across words, phrases, and sentences. This emphasis on "lexically based integration" (p. 29) or "comprehending words" (p. 26) highlights the important role of the lexicon, which in the Reading Systems Framework consists of meaning, morphology, and syntax. Research confirms morphology, vocabulary, and syntax as important components of language (e.g., Foorman et al., 2015; Kieffer et al., 2016; Uccelli et al. 2015). Hence, we explore the relative magnitudes of these language areas in supporting reading comprehension to better understand word-to-text integration and more specifically, the role of language in supporting reading comprehension.

In our study, we define morphological knowledge to include knowledge of units of meaning (i.e., prefixes, root words, and suffixes) and “awareness of morphemic structures of words and the ability to reflect on and manipulate that structure” (Carlisle, 1995, p. 194). Vocabulary knowledge is “knowledge of word meanings” (Pearson et al., 2007, p. 284) and syntax knowledge is knowledge of word order, grammatical rules, and connectives used to combine words to create unique combinations of meaning (Taylor et al., 2012). We focus on these three language areas modeled in the lexicon rather than aspects of language more closely related to form (i.e., phonological awareness, orthographic knowledge, decoding). This fits developmentally as research indicates decoding plays less of a role in reading comprehension at this age (Foorman et al., 2015, 2018; Garcia & Cain, 2014; Ricketts et al., 2020) whereas language comprehension is more challenging for these readers and plays a larger role (Catts et al., 2006; Foorman et al., 2015, 2018; Florit & Cain, 2011; Garcia & Cain, 2014; Ricketts et al., 2020). It also fits theoretically as the Reading Systems Framework states that “a particular point of focus is the lexicon” (Perfetti & Stafura, 2014, p. 24). Given recent research suggesting decoding and language comprehension explain unique and common variance in reading comprehension (Duke & Cartwright, 2021; Foorman et al., 2018; Taboada Barber, Cartwright, Hancock, & Lutz Klauda, in press), we aim to explore the full role of the lexicon (and in particular morphology, vocabulary, and syntax) in reading comprehension by considering the role of these language areas in explaining unique and also common variance (i.e., variance shared with decoding, hence not controlling for decoding). Specifically, our study uses a theoretical and developmental lens to explore the relative importance of morphology, vocabulary, and syntax to better understand the word comprehension highlighted within the Reading Systems Framework.

The Reading Systems framework encourages "researchers to examine specific systems and subsystems and the interactions among them" (Perfetti & Stafura, 2014, p. 34). Theoretically, word-to-text integration updates the situation model with the meanings of individual words (i.e., vocabulary), many of which may be unfamiliar but can be figured out from their morphological makeup (i.e., morphology) and through the surrounding context (i.e., vocabulary and syntax). It also involves parsing the complicated syntax of academic language (i.e., syntax), integrating meanings across phrases and sentences. Perfetti's (2007) Lexical Quality Hypothesis adds a further layer to considering systems and subsystems: "Underlying efficient processes are knowledge components; knowledge about word forms (grammatical class, spellings and pronunciations) and meanings" (p. 359). Studies like Goodwin, Gilbert, Cho, & Kearns (2014) applied these ideas to show that the lexical representations of adolescents included these different types of knowledge related to morphology (i.e., a morpheme's spelling, pronunciation, and meaning). Hence, combining the Reading Systems Framework with the Lexical Quality Hypothesis suggests considering each language area as broad (i.e., containing multiple subsystems or skills) and then determining the relative contributions of each system and subsystem as a way of better understanding the role of the lexicon in word-to-text integration.

This study is novel because while research has modeled the contributions of language—and more specifically of morphology, vocabulary, and syntax—to reading comprehension (Deacon & Kieffer, 2018; Foorman, et al., 2015, 2018; Gottardo et al., 2018; Kim et al., 2019; Tomblin & Zhang, 2006), less is known empirically regarding the relative contributions of these language areas. That is because the current literature models the total contribution (i.e., total explained variance) of all language predictors in a model or the additional contribution of a single language predictor when controlling for other language predictors. While these findings are important, the dependency of the findings on the covariates within the model make it difficult to ascertain the full role of each separate language construct. While recent work has disentangled the common and unique variance shared among language predictors (Foorman et al., 2018; Gottardo et al., 2018), little is known regarding whether certain predicators are more important than others. Such relative importance can guide theory and research as well as classroom applications by identifying areas for instructional focus. Hence, our study explores the relative importance of language systems to deepen understanding of word-to-text integration. To do this, we use dominance analysis to estimate the relative magnitudes of morphology, vocabulary, and syntax over multiple possible models, allowing for a more comprehensive estimation of relations overall.

Models of Language

We start by considering potential conceptualizations of language involved in word-to-text integration. While language can be thought about in different ways (see LARRC, 2015), when considering young adolescents' academic reading achievement, comprehension of written academic language is a priority. This contrasts with how language is often conceptualized (i.e., via oral language or as language proficiency, LARRC, 2015), so we follow others, like Kieffer and Lesaux (2012), in considering reading-based measures of language involving the language of school texts (Schleppegrell, 2012). Such texts tend to communicate dense and abstract ideas via more complex syntactic structures (including nominalization, anaphora, etc.) and low-frequency, morphologically complex words (Nagy & Townsend, 2012; Uccelli, et al, 2015), many of which involve "abstract representations of processes and relationships…and cannot be easily conveyed via pictures"(Kieffer & Lesaux, 2012, p. 354) and which also convey their links to morphology via spelling (i.e., *magic*, *magician*) rather than oral pronunciation. In other words, written (and academic) language is different from oral language beyond input: the written symbols convey not only decoding information but also meaning, making it important to consider written school-based language for adolescents.

Next, research confirms the Reading Systems Framework's emphasis on morphology, vocabulary, and syntax as key parts of the lexicon. For example, Kieffer et al. (2016) showed strong fit of such a model for 3rd-6th graders and also showed that language comprehension conceptualized this way significantly contributed to reading comprehension. In fact, a growing body of work with readers ranging from 1st to 10th grades supports this three-part model of language and its link to comprehension (Deacon & Kieffer, 2018; Foorman, et al., 2015, 2018; Gottardo et al., 2016; Kim et al., 2019; Tomblin & Zhang, 2006). Missing from this work, though, is identification of the relative contribution of each language area. Below, we describe what is known about the potential relative contribution of morphology, vocabulary, and syntax. For morphology, recent work suggests different roles of different subsystems (i.e., skills) of morphology for young adolescents (Goodwin et al., 2017; 2020a,b; 2021), hence we expand our study to explore the relative role of different morphology skills and then consider how these relative roles link to the contributions of vocabulary and syntax more broadly.

Dimensions of Morphology, Vocabulary, and Syntax and their Contributions to Comprehension

Morphology

The contribution of morphology to reading comprehension is well-known (see Nagy et al., 2014 for overview). For adolescents, derivational morphological knowledge is especially important as derivations (i.e., affixes adjusted to change meaning and grammatical category) convey nuanced meanings within text (i.e., *governmental restrictions*; Nagy & Anderson, 1984) and derivational understandings are continuing to develop across middle school, in contrast to inflectional understandings which are typically mastered by this age (Tyler & Nagy, 1989).

Overall, research suggests the contribution of morphology is both unique and related to vocabulary and syntax, as derivational affixes play semantic and syntactic roles. For uniqueness, Kieffer and Lesaux (2012) showed that morphology and vocabulary were unique dimensions for sixth graders and other studies indicate the relation of morphological knowledge to reading comprehension holds beyond vocabulary (Levesque et al., 2019; Nagy et al., 2006) and beyond vocabulary and syntax (Deacon & Kieffer, 2018; Gottardo et al., 2018) for students ranging from third to ninth grade. Research also indicates overlap: Gottardo et al.'s (2017) commonality analysis with Spanish-speaking ELLs from 9 to 13 years of age suggests most of morphology's contribution to reading comprehension (2.9% unique, 43% common) is via overlap with vocabulary (14%) and overlap of vocabulary and syntax (27%). Hence, research seems to indicate morphology works uniquely and in concert with these other language areas, but relative magnitudes are unknown because these findings are specific to the variables in the model (rather than averages across different possible models).

This uniqueness and overlap considered above relates to how morphology is measured, which itself is important to unraveling morphology's relative importance to reading comprehension. The studies above tended to assess morphology unidimensionally, which, while similar to other work, contrasts with recent studies indicating multidimensionality of morphology with young elementary students through middle school students (Apel et al., 2013; Goodwin et al., 2017; Goodwin et al., 2020a,b, 2021). The dimensions relate to the terms used to describe morphological knowledge, such as morphological awareness, morphological decoding, morphological analysis, or even suffix awareness, which themselves relate to how morphology sits at the intersection of language systems and conveys semantic, syntactic, phonological, and orthographic information. For example, morphological awareness involves general awareness of how morphemes are combined to convey meaning: this relates to understanding how morphemes can be manipulated and combined. Additionally, morphological decoding involves using morphemes' phonological and orthographic information (i.e., Morphological-Orthographic/Phonological Knowledge); morphological analysis or problem- solving involves using morphemes' semantic information (i.e., Morphological-Semantic-Knowledge); and suffix awareness involves using morphemes' syntactic information (i.e., Morphological-Syntactic-Knowledge).

These dimensions, conceptualized as components or skills within morphology, have been shown to differentially contribute to reading comprehension. For example, Lam et al. (2020) when considering 2nd and 3rd graders showed that while both morphological awareness and suffix awareness predicted reading comprehension, only suffix awareness predicted beyond autoregressive controls. Similarly, Levesque et al. (2019) reported that, when considering 3rd and 4th graders and when controlling for prior performance, morphological analysis contributed significantly to growth in reading comprehension, whereas morphological awareness did not. Additionally, Levesque et al. (2017) showed that morphological awareness contributed to different mediators, including morphological decoding and analysis, which then supported reading comprehension for third graders. In terms of 7th and 8th graders, Goodwin et al. (2017) showed that general morphological knowledge and morphological meaning contributed positively to reading comprehension and vocabulary whereas morphological word reading and spelling did not. Hence, the relative importance of morphology and understanding of its role in reading comprehension depends on how morphology is operationalized, leading to our consideration of the relative importance of different morphology skills in supporting reading comprehension.

Vocabulary

For vocabulary, research has long indicated that vocabulary predicts reading comprehension, with recent work highlighting vocabulary knowledge as multifaceted including "knowledge of its definition, but also knowledge of the multiple related meanings and shades of meaning for the word, knowledge of its semantic associations, [and] knowledge of its meanings in different contexts," (Kieffer & Lesaux, 2012, p. 348). Cross-sectional studies of upper elementary and middle schoolers have consistently found that vocabulary uniquely predicts reading comprehension (Li & Kirby, 2015; Gottardo et al., 2018; Oullette, 2006; Oullette & Beers, 2010) with longitudinal studies indicating a unique role in reading comprehension development (Oakhill & Cain, 2012; Quinn et al., 2015; Verhoeven & Van Leeuwe, 2008). Importantly, studies have shown vocabulary's unique role when controlling for syntax and word reading skills for fourth graders (Deacon & Kieffer, 2018) and middle school students (Foorman et al., 2015; Gottardo et al., 2018; Sorenson Duncan et al., 2020). Few studies unravel the magnitude of vocabulary's relative contribution, although Gottardo et al. (2017) found for ELLs ages 9 to 13 uniqueness (6.5%) and overlap (50.5%) in vocabulary's contribution to reading comprehension with 14% commonality with morphology and 8% with syntax. Deacon and Kieffer (2018) suggested similar magnitudes of contributions for vocabulary compared to morphology and syntax when working with 3rd and 4th graders, but more work in understanding vocabulary's relative contribution is needed.

As vocabulary has been shown to be multifaceted, empirical findings confirm that both vocabulary breadth and depth make unique contributions to reading comprehension (Binder et al, 2017; Li & Kirby, 2015; Oullette, 2006; Silverman et al., 2015; Shiotsu & Weir, 2007; Qian, 1999). These existing cross-age findings from elementary to university students are consistent with how research reviews (Baumann, 2014; Pearson et al., 2007) and theory (Perfetti, 2007) continue to emphasize assessing vocabulary knowledge as multifaceted to specify the full contribution of vocabulary to middle schoolers' word-to-text integration and, ultimately, their reading comprehension.

Syntax

Beyond the word level, syntax, or knowledge and awareness of the order of words and word relationships is important to word-to-text integration (Deacon & Kieffer, 2018; Nagy, 2007; Perfetti & Stafura, 2014; Scott, 2009). Studies of syntax suggest a unique role in supporting reading comprehension (Cain, 2007; Brimo et al., 2017; Mokhtari & Thompson, 2006; Farnia & Geva, 2013; Nation & Snowling, 2000; Nippold, 2017; Nomvete & Easterbrooks, 2019; Shiotsu & Weir, 2007) including beyond word reading, vocabulary, and morphology controls (Deacon & Kieffer, 2018; Foorman et al., 2015; Gottardo et al., 2018; Proctor et al., 2012; Silverman et al., 2015; Sorenson Duncan et al., 2020). Three particular recent studies show the unique contributions of syntax beyond substantial control variables. Sorenson Duncan and colleagues' study (2020) of 11-year-olds found that understanding basic sentences explained about 12% unique variance in their reading comprehension. Gottardo et al.'s (2017) study of 9-13 year old ELLs suggests that syntax explains unique (6%) and common (36.3%) variance in reading comprehension with 8% overlap with vocabulary and 27% overlap with both vocabulary and morphology. Importantly, Deacon and Kieffer's (2018) study of upper elementary students found that "syntactic awareness had a direct, practically important relation to reading comprehension", and suggests that for reading comprehension, syntax is "as practically important as the contributions of more established predictors such as vocabulary and morphological awareness” (p. 79). This underscores the importance of unraveling the relative importance of syntax to reading comprehension, with studies typically considering a singular, unidimensional role .

Halliday (2004) and Schleppegrell (2004) explain why syntax is particularly important for middle schoolers reading academic texts: such texts have denser syntactic structures that complicate comprehension (Frantz et al., 2016; Nation & Snowling, 2000). These structures also include knowledge of connectives, which are words that signal relationships between clauses and sentences, and this knowledge has also been shown to predict comprehension for middle level students (Cain & Nash, 2011; Crosson & Lesaux, 2013; Sanchez et al., 2017; Uccelli et al., 2015). Syntax is also connected to morphology as suffixes carry syntactic information supporting word-to-text integration. Hence, unraveling the relative contributions of these language areas is important.

The Current Study

Our study explores the relative contributions of morphology, vocabulary, and syntax to reading comprehension for young adolescents. Framed in the Reading Systems Framework (Perfetti & Stafura, 2014), we focus on these three language areas that are modeled within the lexicon and which are suggested to play a key role in word-to-text integration. Because research suggests morphology is multidimensional, we (1) explore the relative roles of four morphology skills in supporting reading comprehension to better understand the full role of morphology in reading comprehension. Next, we (2) explore the relative roles of the three key language areas identified in the lexicon: morphology (operationalized via four skills consisting of seven tasks), vocabulary (operationalized by a single score representing multifaceted knowledge from four tasks), and syntax (assessed unidimensionally). Ultimately, our study informs models of language and reading comprehension like the Reading Systems Framework by identifying the relative contributions of language areas to reading comprehension.

Method

Participants

Our three-year study partnered with an urban district in the Southeastern United States. This analysis involved students who had taken the computer-adaptive version of our assessment during Year 3 (see Goodwin et al., 2020a,b; Goodwin et al., 2021 for further details of the larger study). This sample included 1,027 fifth through eighth graders (*N*=405 fifth graders, 265 sixth graders, 161 seventh graders, and 196 eighth graders, approximate ages 10-15) who were 53% female, 42.8% White, 30.4% Black, 22.3% Latino, and 4.5% Asian. This sample had 30.6% students classified as economically disadvantaged and 7.3% were identified as ELLs, speaking a range of home languages with Spanish the most prevalent.

Measures

Language: Monster, P.I.

We used a gamified, computer-adaptive language assessment entitled Monster, P.I. to gather data on derivational morphology, vocabulary, and syntax. This assessment framed questions within a larger storyline. Students hunted down a monster who had destroyed scenes in a city by solving items and earning clues to the monster's identity (See Goodwin et al., 2020, in press for further details and validation evidence). The computer-adaptive test meant that while each task had a large pool of items, each student took only those at their ability level. The assessment was group-administered on iPads by trained research assistants in a single session (all measures were presented in print with vocabulary and syntax measures read aloud)[1]. Students usual took between 25-45 minutes to complete the assessment. Validation work showed reliability and validity of scores (obtained from a multidimensional IRT analysis, see Goodwin et al., 2020a,b) for four morphological skills, a main vocabulary score, and a main syntax score. Importantly, this assessment assessed both morphological knowledge and vocabulary in the broad senses recommended within the literature (see Appendix A for more information). We describe each task below and summarize their component tasks in Table 1, which also includes marginal reliabilities and total potential items in the pool for each skill. Monster, P.I. was administered in Spring.

Morphology

Morphological Awareness (Skill 1). Morphological awareness is assessed by two tasks that tap into the ability to identify morphemes. The first task, Odd Man Out, was adapted from Ku and Anderson (2003) and participants saw three words and identified the word that did not share a morpheme. Word trios varied whether they overlapped in suffixes, prefixes, or root words. The second task, Meaning Puzzles, asked participants to identify the answer choice that shared a morpheme with the given target word. This task was adapted from intervention (Goodwin, 2016) and assessment work (Pacheco & Goodwin, 2013). Answer choices overlapped orthographically and phonologically, but only one answer choice overlapped morphologically with the target word. These tasks assessed students' identification of morphological rather than orthographic overlap. The marginal reliability of scores in this sample was .83.

[1] Morphological measures were not read aloud after pilot data from year 1 indicated no significant differences on items read aloud versus provided only in print (see Goodwin et al., 2019).

Morphological-Syntactic-Knowledge (Skill 2). Representing suffix awareness (i.e., Lam et al.), two tasks assessed participants' ability to either choose or produce the word with the appropriate suffix to complete a sentence (i.e., suffix awareness). The Real Word Suffix task, adapted from Tyler and Nagy (1989), provided a sentence and a blank. Participants chose the correct word from four answer choices. Each answer choice had the same root, but a different suffix. The Making it Fit task, adapted from Carlisle (1995), provided participants with a base word that they had to adapt by adding the appropriate suffix to complete the sentence. Both tasks assessed participants' awareness of the syntactic role of suffixes. The marginal reliability of scores in this sample was .85.

Morphological-Semantic-Knowledge (Skill 3). Representing what has been termed morphological analysis (Levesque et al., 2019), the knowledge of how semantic meaning is conveyed via morphemes was assessed by a task adapted from Anglin's (1993) word solving work as well as Tyler and Nagy's (1989) work. Framed as a detective task, called Word Detectives, participants were presented with a morphologically complex word within a sentence and encouraged to look for clues in the word and in the sentence to help figure out the word's meaning. The marginal reliability of scores in this sample was .73.

Morphological-Orthographic/Phonological-Knowledge (Skill 4). Representing what has been termed morphological decoding, two tasks were used to assess participants' knowledge of how morphemes convey orthographic and phonological information. For the orthographic information, a Morphological Spelling task adapted from Carlisle (1988) and Nunes et al. (2012) was used where students spelled the morphologically complex word heard using the iPad's keyboard. For phonological information, a Morphological Decoding task was used, although adjusted to be delivered via iPad. Participants saw a target word and heard three pronunciations via headphones. They then chose the correct pronunciation, with distractors being the incorrect responses most often obtained from a pilot reading task where middle schoolers had read a list of words aloud into an audio recorder. The marginal reliability of scores in this sample was .82.

Vocabulary. A single score for vocabulary was obtained from performance on four vocabulary tasks. This score captured the multifaceted nature of vocabulary knowledge through a global estimate of four different vocabulary tasks estimated from a bi-factor model in the original validation study (Goodwin et al., 2019). Four tasks included identifying the correct definition of a word, matching a word to a synonym or antonym, determining the relationship between two word pairs, and determining the potential polysemy of a word by choosing multiple correct meanings for a given word. These four tasks assess not just breadth but conceptual relations and depth of knowledge of polysemous words. The marginal reliability of scores in this sample was .81.

Syntax. A single score for syntax was obtained via a measure adapted from Foorman et al. (2017). Participants were given two or three sentences. They then had to choose the best answer that combined those sentences into one new sentence. Five types of connectives were used, including additive (i.e., *and, as well, further*); causal (i.e., *so, in order that, because*); temporal (i.e., *before, after, finally*); logical (i.e., *similarly, provided that, in case*); and adversative (i.e., *but, though, however*). This task is similar to the sentence combining task in the Test of Language Development (TOLD, Hammill & Newcomer, 2020), although assessed with text read aloud and presented onscreen rather than purely orally. The marginal reliability of scores in this sample was .70.

Standardized Reading Comprehension: Measures of Academic Progress [MAP]

A standardized, nationally normed, district-used measure (Measures of Academic Progress [MAP] Northwest Evaluation Association [NWEA], 2014*)* assessed reading comprehension via a computer-adaptive, multiple-choice reading test. Participants read literary and informational texts and answered questions and also matched sentences to pictures or diagrams for vocabulary items. Such actions involved the word-to-text integration (Perfetti & Stafura, 2014) that is at the heart of this study. Because it was computer-adaptive, students completed about 25-30 items at their level, taking 20-40 minutes (Merino & Beckman, 2010). The test is aligned to US reading standards and has strong reliability (.90-.95) as well as concurrent validity (NWEA, 2014). MAP uses Rasch modeling to provide scores in Rasch units (RIT) that allow for comparisons across grades. Overall reading comprehension scores were used including all item types. Spring MAP scores were used, which were administered by teachers as part of typical district practices.

Data Analysis

Dominance Analysis (Azen, 2013; Azen & Budescu, 2003) was used to determine what uniquely predicted reading comprehension scores and at what magnitude (see Appendix B for further details on Dominance Analysis). We choose this analysis because robust implications of regression coefficients or a model R^2 are limited by which predictors and the number of predictors that are included in a model (Azen & Budescu, 2003). Dominance analysis allows a rank ordering of the contribution of predictors by first estimating all possible main-effects regression models (i.e., all subsets regression). The results of each model, ranging from the inclusion of 0 to n variables are then synthesized via the model R^2. Azen and Budescu argue that one predictor is valued as more important than others if it has a greater contribution in all other possible subset models where only one of the two variables is entered into the equation. Dominance analysis becomes increasingly important to test the relative importance of variables as the number of predictors increases. The average R^2 contribution and unique contribution to size *k* models was evaluated and reported as was the level of dominance of each predictor in pair-wise contrasts of the predictors.

Levels of dominance were set by reviewing two statistics. The sample-based D*ij* coefficient in dominance analysis denotes whether the level of dominance in the sample between each predictor *i* over predictor *j* pairing can be observed. The reproducibility coefficient (R) is the percent of bootstrapped conditions where the level of dominance was observed with lower R values indicating weaker confidence. Complete dominance is understood to be when predictor *i* explains more unique variance for *every* subset model than predictor *j*. Conditional dominance indicates the average additional contribution *within* model size *k* (e.g., 1 predictor only, 2 predictors only, etc.) for predictor *i* is greater than predictor *j*. General dominance is the weakest form of dominance when the average additional contribution *across* all model sizes for predictor *i* is greater than predictor *j*. Because the bootstrap process for dominance analysis evaluates pairwise dominance relations using variable *i* compared to variable *j*, each of the predictors can be represented as either an *i* or a *j* variable.

Two sets of dominance analyses were estimated using the dominance analysis package in R software (Navarrete & Soares, 2019). The first dominance analysis estimated levels of dominance among just the four morphology skills, and the second dominance analysis considered the morphology skills, vocabulary, and syntax.

Results

Data and Preliminary Analysis

Preliminary review of the data showed that <1% of data were missing for morphology measures, vocabulary, and reading comprehension, with 2.3% missing data on syntax. Little's test of data missing completely at random (MCAR) resulted in a fail to reject the null hypothesis that data were MCAR, $\chi^2(6) = 0.99$, $p > .500$. A review of the data did not suggest that patterns were non-ignorable; thus, multiple imputation via the mice package in R software (van Buuren & Groothuis-Oudshoorn, 2011) was used. Ten imputations were conducted with data synthesized and aggregated at the individual level for the purpose of analysis. Table 2 provides the descriptive statistics and correlations among measures. The mean scores for the pre-imputation Monster, PI measures were all close to 500, which reflects this sample being close to the normative mean of 500 using vertical scaling. The mean MAP reading comprehension score was 218.17 ($SD = 15.80$), which indicated approximately average scores (national median scores range 5th gr=212 to 8th gr=220; NWEA, 2015). Correlations ranged from $r = .51$ in the pre-imputed data between syntax and morphology Skill 4 to $r = .71$ for both the relation between Skills 1 (Morphological Awareness) and 3 (Morphological-Semantic-Knowledge) and Skill 1 (Morphological Awareness) and vocabulary. Deviations in the pre- and post-imputed correlations ranged from .01 (e.g., between Skills 1 and 2) to .08 (i.e., between Skill 3 and Vocabulary). The standardized mean difference in pre- and post-imputed mean scores for Syntax did not exceed $|d| = .05$.

Dominance Analysis

RQ 1: Morphology dominance results. Dominance analysis among the morphology skills (Table 3) showed that Skill 1 (Morphological Awareness) contributed the most unique variance across all *k* predictor models with an average of 17% and ranging from 3% with three predictors in the model to 48% when no other predictors were included. Skill 2 (Morphological-Syntactic-Knowledge) explained 15% unique variance on average, ranging from 3% with three predictors in the model to 44% with no other included predictors. Skill 3 (Morphological-Semantic-Knowledge) explained 15% unique variance on average, ranging from 2% when three predictors were in the model to 45% with no other included predictors. Skill 4 (Morphological-Orthographic/Phonological-Knowledge) uniquely explained 13% on average ranging from 2% with three predictors in the model to 39% with no other included predictors. Testing levels of dominance among the predictors (Table 4) indicated that Skill 1 (Morphological Awareness) completely dominated Skill 3 (Morphological Semantic Knowledge, R = .84) and Skill 4 (Morphological-Orthographic/Phonological-Knowledge, R = .73) and generally dominated Skill 2 (Morphological-Syntactic-Knowledge, R = .90). Skill 2 generally dominated Skills 3 (R = .53) and 4 (R = .90) but it should be noted that the reproducibility for Skill 2 vs. Skill 3 was low (.53). Skill 3 generally dominated Skill 4 (R = .89). Overall, the combination of Skills 1-4 explained 50.7% of the variance in MAP reading comprehension.

RQ2: Morphology, vocabulary, and syntax dominance results. The inclusion of vocabulary and syntax into the second dominance analysis changed the magnitude of results reported in Table 3. Each average contribution changed: Skill 1 (Morphological Awareness) changed from 17% to 12%; Skill 2 (Morphological-Syntactic-Knowledge) changed from 15% to 10%; Skill 3 (Morphological-Semantic-Knowledge) changed from 15% to 10% and Skill 4 (Morphological-Orthographic/Phonological-Knowledge) changed from 13% to 10%. The average contribution of Vocabulary was 13% and ranged from 2% when the other five predictors were included to 50% with no additional predictors; and the average contribution of Syntax was 9% ranging from 1% with five predictors in the model to 39% with no additional predictors.

Levels of dominance (Table 5) for this model showed that Skill 1 (Morphological Awareness) completely dominated Skill 3 (Morphological-Semantic-Knowledge, R = .65) and generally dominated Skill 2 (Morphological-Syntactic-Knowledge, R = .89), Skill 4 (Morphological-Orthographic/Phonological-Knowledge, R = .94), and Syntax (R = .98). Skill 2 generally dominated Skill 3 (Morphological-Semantic-Knowledge, R = .47), Skill 4 (Morphological-Orthographic/Phonological-Knowledge, R = .67), and Syntax (R = .87) but the reproducibility was low against Skill 3 (R = .47). Skill 3 (Morphological-Semantic-Knowledge) generally dominated Skill 4 (Morphological-Orthographic/Phonological-Knowledge, R = .67) and Syntax (R = .88); Skill 4 (Morphological-Orthographic/Phonological-Knowledge) generally dominated Syntax (R = .75). Vocabulary completely dominated Syntax (R = .86), conditionally dominated Skills 1 (Morphological Awareness) (R = .72), 2 (Morphological-Syntactic-Knowledge, R = .90), and 3 (Morphological-Semantic-Knowledge, R = .93), and generally dominated Skill 4 (Morphological-Orthographic/Phonological-Knowledge, R = .97). Overall, the combination of Skills 1-4, Vocabulary, and Syntax explained 62.9% of the variance in MAP reading comprehension.

Discussion

The current study suggests insights into the relative importance of the meaning-making language skills and knowledge that underlie the strong relation between language and reading comprehension and which are modeled, but not unraveled, in the Reading Systems Framework (Perfetti & Stafura, 2014). The novelty of our study is twofold. First, we considered multiple language areas (morphology, vocabulary, and syntax) and then subsystems including multifaceted vocabulary and multiple morphological skills (Morphological Awareness, Morphological-Syntactic Knowledge, Morphological-Semantic Knowledge, Morphological-

Orthographic/Phonological Knowledge). Here, we show that each of the language areas (vocabulary, morphology, syntax) modeled in the lexicon in the Reading Systems Framework play an important and non-ignorable role in reading comprehension, and for morphology, the four specific skills play meaningful roles as well. Hence, we confirm and extend the understanding of lexicon as it supports word-to-text integration within the Reading Systems framework.

Second, we modeled the relative importance of these language areas because such understandings help us refine theory and focus assessment and instructional efforts. These additions align with the Reading Systems Framework's dual emphasis on word-to-text integration across words, phrases, and sentences as well as its emphasis on considering systems and subsystems and their interactions. Overall, the Reading Systems Framework (Perfetti & Stafura, 2014) suggested each of these areas were similarly important and integral to the lexicon. Also, research (i.e., Deacon & Kieffer, 2018; Foorman, et al., 2015, 2018; Gottardo et al., 2016; Kim et al., 2019; Tomblin & Zhang, 2006) had established the unique and overlapping roles of these language areas—or skills within these areas (Goodwin et al., 2017; Levesque et al., 2017), but study findings were dependent on the predictors in the model. Our study suggests while each area played an important role, some—especially vocabulary and morphological awareness—played particularly important roles and hence should be prioritized within theory, research, assessment, and instruction.

Understanding Contributions of Morphological Skills

As mentioned, the Reading Systems Framework identifies morphology as a key component of the lexicon, which can then support reading comprehension. Our findings confirm and extend this, showing the extensive ways morphology contributes to reading comprehension:

four morphology skills each explained meaningful variance in reading comprehension across all models, ranging from 17% for Morphological Awareness to 13% for Morphological-Orthographic/Phonological-Knowledge, and together explaining half of the variance in standardized reading comprehension. Hence, the four skills explored in our study add detail to the types of morphological information that are components of word-to-text integration. Specifically, we found evidence for roles of Morphological Awareness, Morphological-Syntactic Knowledge, Morphological-Semantic Knowledge, and Morphological-Orthographic/Phonological Knowledge, each of which represents a different source of linguistic information conveyed by morphemes.

The strength of dominance analysis is to suggest a relative order of importance, indicating what may matter more for instructional focus. Unsurprisingly, the most critical skill was Morphological Awareness (Skill 1), which completely dominated Skills 3 and 4 and generally dominated Skill 2. Hence, the ability to identify morphemes and morphologically related words plays a particularly key role in word-to-text integration even when compared to other morphology skills. The dominating role of this skill suggests that this ability is foundational to accessing and applying the other morphological information represented by the other morphological skills in our model. Hence, when considering morphology within the Reading Systems Framework, morphological awareness is a core skill that underlies accessing and applying the syntactic, semantic, and orthographic/phonological morphological knowledge present in the lexicon. While this does not mean the other skills are unimportant, it does suggest that morphological awareness is foundational. This helps explain findings like Levesque et al. (2017), which showed morphological awareness contributed reading comprehension via mediators (morphological skills like morphological decoding-similar to Morphological-

Orthographic/Phonological-Knowledge—and morphological analysis—similar to Morphological-Semantic-Knowledge). In that study, morphological awareness predicted/supported the other morphological skills, which then contributed to reading comprehension. Our findings confirms the role of well-studied aspects of morphology, especially morphological awareness, but also morphological decoding and morphological problem solving. It then suggests a role for a less studied aspect of morphology, morphological-syntactic knowledge (i.e., suffix awareness, Lam et al., 2020). Overall, our findings add understanding to the Reading Systems Framework by identifying skills and relative roles for these morphological skills within reading comprehension.

Understanding Contributions of Language Areas

Next, we consider the full suite of language skills explored and represented within the lexicon in the Reading Systems Framework. Our results confirm and extend the Reading System Framework: each language area in the lexicon including vocabulary, the four skills within morphology, and syntax were shown to be important. Each explained meaningful variance, albeit at slightly different magnitudes. For example, the following average amounts of additional, unique variance were explained in reading comprehension across models: 13% for vocabulary, 12%-10% for each morphology skill, and 9% for syntax. In terms of extending, our findings of relative magnitude highlight the importance of vocabulary and morphological awareness in supporting reading comprehension. Vocabulary had a larger relative contribution than the other language predictors, completely dominating syntax and conditionally or generally dominating each of the morphological skills (separately considered). Importantly, vocabulary knowledge was assessed broadly, including definitional, relational, analogical, and polysemous knowledge, so it may be that multifaceted vocabulary knowledge is particularly important to reading comprehension. Hence, this extends the Reading Systems framework to highlight the foundational, and non-surprising, role of word meanings in word-to-text integration.

Results related to relative magnitude also showed the continued importance of the morphological skills, although they again varied in importance, with Morphological Awareness playing the most important role, followed by Morphological-Syntactic-Knowledge, Morphological-Semantic-Knowledge, and Morphological-Orthographic/Phonological-Knowledge based on the dominance analysis results. Here, each skill was considered separately in terms of relative importance to reading comprehension. Hence, it may be that when predicting reading comprehension, each morphological skill separately plays a role, but a relatively smaller role than multifaceted vocabulary (which was considered as a single predictor whereas morphology was considered via four separate skills).

Individually, the morphology skills played important roles, often dominated syntax, and were not fully dominated by vocabulary. Hence, while vocabulary may be particularly crucial, morphology and in particular, morphological awareness, also showed relative importance and hence should be considered from a theoretical, research, assessment, and instructional perspective. Deacon and Kieffer (2018) suggest a similar role for morphology compared to syntax and vocabulary, whereas Gottardo et al (2017) indicated smaller role, but these studies conceptualized morphology as unidimensional, assessed with a single measure. By assessing morphology multidimensionally, we showed a more complete range of morphological supports for reading comprehension.

Second, syntax did play a meaningful role similar to what has been shown in research (e.g. Crosson & Lesaux, 2013), but was consistently dominated by vocabulary and the morphology skills. With that said, morphological-syntactic-knowledge explained meaningful variance separate from our syntax measure. It also showed dominance over some other morphological skills and syntax more generally. Hence, whereas typical syntax measures focus on combining sentences or word order, the importance of morphological-syntactic-knowledge unique from general syntactic knowledge suggests a broader role for syntax at the morpheme, word, phrase, sentence, and across-sentences level.

Third, vocabulary and Morphological Awareness (Skill 1) appear to contribute more strongly than the other morphology skills and syntax, but the distinction is merely a few percentage points. Therefore, prioritizing semantic knowledge in instruction is justified, but cannot be done at the expense of the other important skills identified here.

Limitations

While moving the field forward, certain limitations must be considered. This is correlational study exploring a particular model of language, and future work should unravel how other components of language underlie the word-to-text integration processes using various research methods. We also used reading-based measures of language, which means that performance on our language-focused measures cannot be separated from word reading skills. This is an important limitation and suggests potential avenues for future research. With that said, we made this decision for two key reasons. First, based on our theoretical framing and recent emphases in the field, we prioritized including the full role of these language areas in reading comprehension. For example, work by Duke and Cartwright (2021) highlights the importance of shared variance between word reading and listening comprehension in explaining reading comprehension. This is because many predictors of language comprehension similarly support word reading. For example, vocabulary (Tunmer & Chapman, 2012a,b) and morphological knowledge (see Nagy, Carlisle, & Goodwin, 2014) supports word reading. Hence, controlling for word reading would parcel out these supports rather than include them as part of the relative role of language areas in supporting reading comprehension—including supports of mediators like word reading. Second, our focus was on 5th thru 8th graders (i.e., approximately ages 10-14), which tends to be an age understudied and an age where decoding plays less of a key role in reading comprehesion. For example, work by Foorman et al. (2015) has showed that above grade 4, decoding did not make a unique contribution to reading comprehension and instead, "The vast proportion of variance in the reading comprehension factor in fourth–10th grades was accounted for by a general oral language factor." (p. 896). This was also confirmed by Foorman et al. (2018). Garcia and Cain's (2014) meta-analysis provides further support as across the 55 studies investigated, results showed that age 10 seemed to be a key moment in which the correlation between reading comprehension and decoding shifted and lessened. Ricketts, Lervåg, Dawson, Taylor, and Hulme (2020) provided yet additional support as for students across ages 12-14 (the oldest in our sample), growth in word reading was small and rank-order stability was quite high. Hence, our decision made theoretical and practical sense, but leaves room for future work to explore additional nuances. Future research should also consider differences for different groups of readers like readers of different ages, emergent bilingual students, students with low vocabulary scores, and struggling readers.

Also, future research should consider alternative conceptions of syntax as our measure was unidimensional and considered connectives and clause order together. Furthermore, findings may be specific to this reading comprehension task and limited to consideration of these language variables rather than other variables important for reading (i.e., motivation, executive functioning, etc). Similarly, the relative importance of these predictors may depend on the characteristics of the text being comprehended (Kim, 2020), including the difficulty of the vocabulary, the number of multimorphemic words, the number of embedded clauses, etc. This links to our focus on academic language: it is likely that morphology, syntax, and vocabulary also play important roles in comprehending texts with less academic language, so future work should consider such differences. Overall, reading comprehension depends on characteristics of readers, texts, and tasks (Snow, 2002) meaning future research should unravel specifics in these areas. Future work may also seek to extend the methodology here by including structural equation models that would both specifically model the unreliability in measurement and afford new opportunities for latent dominance analysis.

Conclusions

Ultimately, our study adds understanding of the relative importance of language predictors to the current literature base. Whereas theories like the Reading Systems Framework portray vocabulary, morphology, and syntax as equal contributors in word-to-text integration, our study adds detail to the theory by confirming important roles for each, but also suggesting a particularly important role for vocabulary and a more extensive role for morphology than is currently modeled. These understandings contribute to theory, research, and practice by suggesting foci for assessment and instruction as well as more extensive conceptualizations of these language areas to consider in theory, research and practice.

Author's Note

We confirm that there is no conflict of interest for any of the authors regarding this manuscript.

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Table 1.

Skills and Measures Described with Examples

#	Skill or Task Name	Description	Example Item
Morphology, four separate scores suggesting four morphology skills (see below)			
Skill 1: Morphological Awareness; *76 potential items*			
1	**Odd Man Out**	*Students were given three words and identified which word did not belong*	estimate* classmate roommate
2	**Meaning Puzzles**	*Students identified the word part most helpful for determining the meaning of that word.*	Accusatory (accurate, accuse*, cushion, custom)
Skill 2: Morphological-Syntactic-Knowledge, which considers how suffixes shift words' parts of speech***;*** *121 potential items*			
3	**Real Word Suffix**	*Students were given a sentence with a missing word. They needed to identify the correct form of the missing word.*	The countries benefited _____ from their membership in the European Union. [financial, financially*, finance, financier]
4	**Making It Fit**	*Students were given a sentence with a missing word & root word. They needed to change the root word to fit the sentence.*	Amphibians are ______ [create] that live on both land and sea. [*creatures]
Skill 3: Morphological-Semantic-Knowledge, which considers using units of meaning to figure out the meanings of words (i.e., morphological word-solving)***;*** *81 potential items*			
5	**Word Detectives**	*Students read sentences and figured out the meanings of challenging morphologically complex words within those sentences.*	The experiment required materials to be **equidistant**. *The materials are:* a) equal in size and weight; *b) spaced out evenly from each other; c) from far away locations; d) ordered spatially
Skill 4: Morphological-Orthographic/Phonological-Knowledge, which is used to support word reading and spelling; *89 potential items, marginal reliability=0.92*			

6	**Morphological Decoding**	*Students identified the correct pronunciation of a morphologically complex word.*	[Words read aloud and not seen onscreen] *a) selective b) select-eyve c) see-lect-eyve
7	**Morphological Spelling**	*Students spelled words that have multiple units of meaning*	1. Knowledge 2. Leverage
Vocabulary, single score which includes definitional knowledge, relationships to other words, and polysemy, *157 potential items,*			
8	**Definition**	*Students identify the correct definition from three choices*	Which of the following is the correct meaning for the word *sweeping*? a) incomparable in beauty, *b)having a wide scope or range, c) making fresh
9	**Synonym or antonym**	*Students match a target word to a synonym or antonym from three choices*	Which of the following is the opposite of the word *famine*? a) adequacy b) success *c) plenty
10	**Analogy**	*Students determine the relationship between two word pairs*	*Just* is to *unequal* as *smooth* is to: *a) rough b) surface c) soft.
11	**Polysemy**	*Students choose multiple correct meanings for a given word*	For *charm*, students answered yes or no to each: Does *charm* mean a piece of a bracelet? [*Yes] Does *charm* mean to make mad? [*No] Does *charm* mean to delight or please? [*Yes]
Syntax, single score representing knowledge of how words are combined to create logical sentences, *34 potential items,*			
12	**Syntax**	*Given two or three sentences, students choose the answer that properly combines those sentences into one new sentence.*	Prompt: Gabby spent most of the summer at a camp. She liked it. She was eager to return home. *a) Although she liked it, Gabby was eager to return home after spending most of her summer at camp. b) After spending most of the summer at camp, Gabby was eager to return home, although she liked it.

*=correct answer

Table 2

Descriptive statistics and correlations among measures

	Pre-Imputation		Post-Imputation									
Variable	*M*	*SD*	*M*	*SD*	*d*	1	2	3	4	5	6	7
1. Skill 1 (Morphological Awareness)	490.59	78.30	489.71	78.29	0.01	1.00	0.66	0.66	0.61	0.65	0.59	0.70
2. Skill 2 (Morphological-Syntactic-Knowledge)	498.41	78.48	499.29	78.92	-0.01	0.67	1.00	0.62	0.55	0.59	0.59	0.67
3. Skill 3 (Morphological-Semantic-Knowledge)	486.98	72.75	487.61	72.94	-0.01	0.71	0.65	1.00	0.59	0.61	0.54	0.66
4. Skill 4 (Morphological-Orthographic/Phonological Knowledge)	493.78	79.56	493.66	79.52	0.00	0.61	0.58	0.61	1.00	0.52	0.49	0.63
5. Vocabulary	502.04	85.16	501.91	84.88	0.00	0.71	0.66	0.69	0.56	1.00	0.60	0.67
6. Syntax	529.17	126.18	528.86	124.30	0.00	0.61	0.60	0.58	0.51	0.65	1.00	0.62
7. Reading Comprehension	218.17	15.80	218.86	15.76	-0.04	0.69	0.66	0.67	0.63	0.70	0.62	1.00

Note. *M* and *SD* are used to represent mean and standard deviation, respectively. All correlations $p < .01$. Upper diagonal of correlation matrix represents pre-imputation correlations. Lower diagonal of correlation matrix represents post-imputation correlations. *d* = Cohen's *d* for standardized difference between the pre-imputed and post-imputed descriptive statistics.

Table 3

Dominance Analysis Average Predictor Contributions of Each Predictor to k-predictor Size by Model

Model	Predictor	Overall Average	0 predictor	1 predictor	2 predictors	3 predictors	4 predictors	5 predictors
Morph Only	Skill 1	0.17	0.48	0.12	0.05	0.03	-	-
	Skill 2	0.15	0.44	0.1	0.04	0.03	-	-
	Skill 3	0.15	0.45	0.1	0.04	0.02	-	-
	Skill 4	0.13	0.39	0.08	0.04	0.02	-	-
Morph + Vocab + Syntax	Skill 1	0.12	0.48	0.12	0.05	0.03	0.01	0.01
	Skill 2	0.10	0.44	0.10	0.04	0.02	0.01	0.01
	Skill 3	0.10	0.45	0.10	0.04	0.02	0.01	0.01
	Skill 4	0.10	0.39	0.09	0.04	0.03	0.02	0.02
	Vocabulary	0.13	0.50	0.13	0.06	0.04	0.03	0.02
	Syntax	0.09	0.39	0.08	0.03	0.02	0.01	0.01

Note: Skill 1=Morphological Awareness; Skill 2=Morphological-Syntactic-Knowledge; Skill 3=Morphological-Semantic-Knowledge; Skill 4=Morphological-Orthographic/Phonological-Knowledge

Table 4

Predictor Dominance Relations and Reproducibility for Morphology Only Model

Contrast	Level of Dominance	*i*	*j*	D*ij*	R
1	Complete	Skill 1	Skill 2	1.00	0.59
2	Complete	Skill 1	Skill 3	1.00	0.84
3	Complete	Skill 1	Skill 4	1.00	0.73
4	Complete	Skill 2	Skill 3	0.50	0.50
5	Complete	Skill 2	Skill 4	1.00	0.58
6	Complete	Skill 3	Skill 4	0.50	0.72
7	Conditional	Skill 1	Skill 2	1.00	0.63
8	Conditional	Skill 1	Skill 3	1.00	0.89
9	Conditional	Skill 1	Skill 4	1.00	0.73
10	Conditional	Skill 2	Skill 3	0.50	0.49
11	Conditional	Skill 2	Skill 4	1.00	0.61
12	Conditional	Skill 3	Skill 4	0.50	0.71
13	General	Skill 1	Skill 2	1.00	0.90
14	General	Skill 1	Skill 3	1.00	0.94
15	General	Skill 1	Skill 4	1.00	0.99
16	General	Skill 2	Skill 3	1.00	0.53
17	General	Skill 2	Skill 4	1.00	0.90
18	General	Skill 3	Skill 4	1.00	0.89

Note. *i* = variable X_i; *j* = variable X_j; D*ij* = Dominance of X_i over X_j; R = Reproducibility.

Table 5

Predictor Dominance Relations and Reproducibility for Morphology, Vocabulary, and Syntax Model

Contrast	Level of Dominance	*i*	*j*	D*ij*	R
1	Complete	Skill 1	Skill 2	0.50	0.61
2	Complete	Skill 1	Skill 3	1.00	0.65
3	Complete	Skill 1	Skill 4	0.50	0.92
4	Complete	Skill 1	Vocabulary	0.50	0.46
5	Complete	Skill 1	Syntax	0.50	0.56
6	Complete	Skill 2	Skill 3	0.50	0.77
7	Complete	Skill 2	Skill 4	0.50	0.91
8	Complete	Skill 2	Vocabulary	0.00	0.76
9	Complete	Skill 2	Syntax	0.50	0.69
10	Complete	Skill 3	Skill 4	0.50	0.97
11	Complete	Skill 3	Vocabulary	0.00	0.73
12	Complete	Skill 3	Syntax	0.50	0.85
13	Complete	Skill 4	Vocabulary	0.00	0.56
14	Complete	Skill 4	Syntax	0.50	0.73
15	Complete	Vocabulary	Syntax	1.00	0.86
16	Conditional	Skill 1	Skill 2	0.50	0.48
17	Conditional	Skill 1	Skill 3	1.00	0.79
18	Conditional	Skill 1	Skill 4	0.50	0.91
19	Conditional	Skill 1	Vocabulary	0.00	0.72
20	Conditional	Skill 1	Syntax	1.00	0.51
21	Conditional	Skill 2	Skill 3	0.50	0.54
22	Conditional	Skill 2	Skill 4	0.50	0.87
23	Conditional	Skill 2	Vocabulary	0.00	0.90
24	Conditional	Skill 2	Syntax	1.00	0.52
25	Conditional	Skill 3	Skill 4	0.50	0.96

26	Conditional	Skill 3	Vocabulary	0.00	0.93
27	Conditional	Skill 3	Syntax	0.50	0.77
28	Conditional	Skill 4	Vocabulary	0.00	0.58
29	Conditional	Skill 4	Syntax	1.00	0.56
30	Conditional	Vocabulary	Syntax	1.00	0.92
31	General	Skill 1	Skill 2	1.00	0.89
32	General	Skill 1	Skill 3	1.00	0.90
33	General	Skill 1	Skill 4	1.00	0.92
34	General	Skill 1	Vocabulary	0.00	0.81
35	General	Skill 1	Syntax	1.00	0.98
36	General	Skill 2	Skill 3	1.00	0.47
37	General	Skill 2	Skill 4	1.00	0.67
38	General	Skill 2	Vocabulary	0.00	0.95
39	General	Skill 2	Syntax	1.00	0.87
40	General	Skill 3	Skill 4	1.00	0.67
41	General	Skill 3	Vocabulary	0.00	0.96
42	General	Skill 3	Syntax	1.00	0.88
43	General	Skill 4	Vocabulary	0.00	0.97
44	General	Skill 4	Syntax	1.00	0.75
45	General	Vocabulary	Syntax	1.00	0.99

Note. *i* = variable X_i; *j* = variable X_j; D*ij* = Dominance of X_i over X_j; R = Reproducibility.

Appendix A: Further Measure Information

This appendix provides further information on the morphological measure within Monster, PI. Validation information can be found in Goodwin et al. (in press). We summarize key points related to validation here focusing on how the four morphological skills were shown to be reliable and valid and then showing evidence that this choice produced comparable estimates in modeling versus modeling with a general factor, adding to the trustworthiness of this approach.

Validation of Morphological Skill Scores: The validation of Monster, PI explored the dimensionality of each construct using multiple-group item response modeling (MG-IRM), which allowed simultaneous testing of the factor structure for the items, the vertical equating of item difficulty, and the vertical scaling of person ability. Skill- and trait-level models were tested. For example, for the trait of morphology, fit was explored for a unidimensional model indicated by all items; a four-factor correlated model of skill factors; a multivariate bifactor model with task-level specific factors and skill-level global factors (described above); and a trifactor model with task-level factors, skill level factors, and a global factor for morphology indicated by all items. For morphology, evidence for the bifactor model was provided where skill-level scores were indicated for modeling. This model fit the data well, $\chi^2(13,666) = 15,250$, CFI = .97, TLI = .96, RMSEA = .015 (90% CI = .012, .025).

Comparability of Multifactor vs General Factor Approaches: Goodwin et al. (2020) shows bivariate associations between Gates Vocabulary (*Gates-MacGinitie Reading Vocabulary Assessment*, MacGinitie et al., 2000) and the morphological skills obtained from the bifactor model as well as the general morphology factor obtained from the trifactor model. Correlations were converted to r-squared to descriptively compare multiple regression analyses predicting vocabulary using morphological skills versus the general. Results show comparable estimates in explained variance between the two factor modeling approaches. With that said, the general factor compared in these analyses is madeup of shared variance from all the items and tasks and stemmed from the trifactor model (task, skill, and global factor), which is both different from a unidimensional model (which showed poor fit) and also a more comprehensive assessment of the full construct of morphological knowledge than a single measure. Hence, both models provide similar results but the use of the morphological skills within the bifactor model allows us to explore relative contributions to answer our research questions. In other words, the skill-level scores provide a more nuanced understanding of the construct and strengths and weaknesses. At the same time, the bifactor model with the four skills shows similar good fit, explains similar amounts of variance, and the scores from the skills maintain adequate levels of reliability: hence we choose to use the morphological skills scores provided by Monster, PI in our modeling.

Appendix B: Dominance Analysis Details

As mentioned, Dominance analysis (Azen, 2013; Azen & Budescu, 2003) allows a rank ordering of the contribution of predictors by first estimating all possible main-effects regression models. The results of each type of model, ranging from the inclusion of 0 to *n* variables are then synthesized via the model R^2. One predictor is valued as more important if it has a greater contribution in all other possible subset models where only one of the two variables is entered into the equation (Azen & Budescu, 2003). Dominance analysis has been widely used in literacy research (e.g., Clemens et al., 2019; Kim & Petscher, 2011; Mellard et al., 2012; Tighe & Schatschneider, 2014; Tighe et al., 2015).

To provide more details, we share an example.

Studying the relation between morphology, syntax, and vocabulary as predictors of reading comprehension, dominance analysis uses $2^{(p-2)}$ subset models to generate all possible R^2 from the included predictors (p). To look at the unique value of morphology, one would take the R^2 from any subset model that includes morphology and subtract the R^2 from a model not including morphology. The unique value of morphology when only one other predictor in the model would be evaluated by looking at the following model comparisons using R^2:

Model 1: (Morphology + Syntax) – (Syntax) = unique value of morphology above syntax

Model 2: (Morphology + Vocabulary) – (Vocabulary) = unique value of morphology above vocabulary

The averaged R^2 across Models 1 and 2 represents the unique value of morphology when one other predictor is in the model. This process repeats, looking at morphology when no other predictors are in the model or all other predictors are in the model. The averaged R^2 across all possible models reflects the average unique contribution of the variable. Without dominance analysis, researchers have few options for predictor importance as the unique R^2 for any model is confounded by its order of entry. In the example above, the importance of morphology differs if syntax is present compared to if vocabulary is present.

Dominance analysis establishes levels of dominance via analysis of two statistics. The dominance of predictor *i* over predictor *j*, where *i* and *j* are each a predictor in a set of predictors, is evaluated via a sample-based D*ij* coefficient that denotes whether the level of dominance in the sample between each *ij* pairing can be observed (See Appendix B). A D*ij* coefficient of 0.5 means that neither predictor dominates the other; 1 indicates that predictor *i* dominates predictor *j*; and 0 means that predictor *j* dominates predictor *i*. The reproducibility coefficient (i.e., R) is a summary coefficient from 1,000 bootstrapped estimates to establish one of three levels of dominance among the predictors and describes the percent of bootstrapped conditions where the level of dominance was observed. A value of 1.00 indicates that the observed dominance of predictor *i* over predictor *j* occurred in 100% of bootstrapped samples. Lower R values show weaker confidence in the level of observed sample dominance based on the bootstraps. D*ij* and R coefficients are helpful as D*ij* gives the direct, summative comparison of how one predictor compares to another in explaining unique variance. The R^2 values from the dominance is helpful for reviewing contributions of predictors across all subset models, but the D*ij* succinctly evaluates the head-to-head comparison of predictors. Similarly, the R coefficient is a useful statistic for looking at the generalizability of D*ij*. That is, if a D*ij* value of 1.0 is observed along with an R of .30 when testing for complete dominance, then we may conclude that predictor *i* completely dominates predictor *j* with the sample data. However, when the sample data were bootstrapped 1,000 times, complete dominance was only observed in 300 of the 1,000 bootstraps. Subsequently, the generalizability of the complete dominance would be weaker in the presence of a lower R coefficient. Complete dominance describes where a predictor *i* explains more unique variance for *every* subset model than predictor *j* (or vice versa). Conditional dominance is where the average additional contribution *within* model size *k* (e.g., 1 predictor only, 2 predictors only, etc.) for predictor *i* is greater than predictor *j* (or vice versa). General dominance is the weakest form of dominance where the average additional contribution *across* all model sizes for predictor *i* is greater than predictor *j* (or vice versa). Because the bootstrap process for dominance analysis evaluates pairwise dominance relations using variable *i* compared to variable *j*, each of the predictors can be represented as either an *i* or a *j* variable.