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Research Article

Morphological Supports: Investigating Differences in How Morphological Knowledge Supports Reading Comprehension for Middle School Students With Limited Reading Vocabulary

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Purpose: The current study takes a practical and theoretically grounded look at assessment of morphological knowledge and its potential to deepen understanding of how morphological knowledge supports reading comprehension for students with limited reading vocabulary. Specifically, we explore how different morphological skills support reading comprehension for students with typical reading vocabulary development compared to students with limited reading vocabulary.
Method: A sample of 1,140 fifth through eighth graders were assessed via a gamified, computer-adaptive measure of language that contained a morphological knowledge assessment. Links to standardized reading comprehension were explored with a focus on determining differences for the 184 students in the sample who showed limited reading vocabulary knowledge. Specifically, multiple regression analyses were used to test for the relation between morphology skills and standardized reading comprehension, as well as the moderator effect of reading vocabulary on the relation between morphological knowledge and standardized reading comprehension.
Results: Findings indicate that the four instructionally malleable morphological skills identified by the assessment differentially supported reading comprehension. These skills were (a) Morphological Awareness, (b) Syntactic Morphological Knowledge, (c) Semantic Morphological Knowledge, and (d) Phonological/Orthographic Morphological Knowledge. Significant interactions for students with limited reading vocabulary were shown in how the skills of Syntactic Morphological Knowledge, Semantic Morphological Knowledge, and Phonological/Orthographic Morphological Knowledge supported standardized Reading Comprehension.
Conclusions: Given the challenges students with limited reading vocabulary have with semantic information, Syntactic Morphological Knowledge and Phonological/Orthographic Morphological Knowledge were particularly supportive, suggesting the compensatory role of these morphological skills. In contrast, Semantic Morphological Knowledge had a negative relationship with Reading Comprehension for students with limited reading vocabulary. Implications for theory, research, and practice are discussed.

Research has consistently shown that morphological knowledge plays an important role in reading comprehension (see Carlisle, 1995, 2003; Kuo & Anderson, 2006; Nagy, et al., 2014) as well as instruction (see Bowers et al., 2010; Carlisle, 2010; Goodwin & Ahn, 2010, 2013). A main area where research is advancing is in considering the role of morphological knowledge more broadly, with recent research suggesting that morphological knowledge is multidimensional (Apel, 2014; Goodwin et al., 2017, 2020). This is important because conceptualizing morphological knowledge as multidimensional allows us to first identify the full contribution of the construct to

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reading comprehension and, second, investigate the different ways that readers, including readers who struggle, apply these skills (i.e., morphological strengths and weaknesses) to reading comprehension.

This study adds to the literature by considering a broader conceptualization of morphological knowledge and its links to reading comprehension for different types of students. We focus on middle school students who demonstrate challenges with lexical access for words presented in print and/or oral language and operationally define these students as having limited reading vocabulary. We focus on this population because morphological knowledge is closely related to vocabulary knowledge, and vocabulary knowledge is key to reading comprehension (Anderson & Freebody, 1985; Kuo & Anderson, 2006; Perfetti, 2007; Wagner et al., 2007). Also, by middle school, vocabulary takes on a particularly important role as the texts middle schoolers are tasked with comprehending tend to include more difficult words and more complex syntax (Hiebert et al., 2018; Nagy & Townsend, 2012). In fact, by middle school, language skills like vocabulary knowledge are the stronger predictor of reading comprehension as compared to word reading skills (Catts et al., 2006; Florit & Cain, 2011; Gough et al., 1996).

Multidimensional Morphological Knowledge

We start by defining our terms and framing them within theory and research. We define "morphological knowledge" as an umbrella term to include conscious (i.e., explicit awareness) and less conscious (i.e., implicit) processing of morphological information (Bowers et al., 2010; Levesque et al., 2019; Nagy et al., 2014). According to models of morphological processing, readers use morphological knowledge to break apart morphologically complex words and access lexical representations that include morphemic units such as prefixes, suffixes, or root words (Schreuder & Baayen, 1995). This occurs automatically with familiar words (i.e., *fearful*) and more strategically with novel words (i.e., *nationalistic*) such that representations can be built and added upon with each encounter. This automatic processing tends to be termed "morphological processing" (Deacon et al., 2008). Comparatively, the strategic processing of morphological units is typically termed "morphological awareness" when it is focused on the ability to manipulate morphemes in language (Carlisle, 1995; Levesque et al., 2019) or morphological analysis (Levesque et al., 2019) when the focus is on purposefully determining the meaning of unknown morphologically complex words. Our operational definition of morphological knowledge includes morphological processing, morphological awareness, and morphological analysis. We also use the term "morphological knowledge" to reflect the different sources of information conveyed by morphemes. According to Perfetti's (2007) lexical quality hypothesis, information related to orthography, phonology, grammar, and meaning are all key components of a word's lexical representation, and this knowledge is processed and simultaneously applied to infer meaning during reading comprehension. Morphological processing theories suggest that, similar to the lexical representations for words, multidimensional lexical representations are present for morphological units (Goodwin et al., 2014; Schreuder & Baayen, 1995). Hence, students access and process the orthographic, phonological, grammatical, and meaning information contained in the lexical representations for roots, suffixes, and prefixes (Seymour, 1997). For example, when considering the morphological makeup of *notation,* a reader might focus on the phonological (e.g., /noteʃən/), semantic (e.g., the process of noting in writing), syntactic (e.g., noun), and/or orthographic (e.g., spelling) information contained in the morphemes—or a combination of this information. Yet, as Quémart et al. (2018) write, "the overt processing of morphemes is not an all-or-none phenomenon, and might be better explained by the convergence of codes…facilitation is even more important when these cues overlap" (p. 8). Hence, we operationalize morphological knowledge as multidimensional to represent the multidimensional nature of the lexical representations of morphological units.

Role of the Orthography

Our multidimensional conceptualization of morphological knowledge extends the well-established literatures that consider morphology in oral language and for children with various language or literacy clinical diagnoses including specific language impairment (SLI), developmental language disorder, and dyslexia (Casalis et al., 2004; Elbro & Arnbak, 1996; Rice & Wexler, 1996). For example, Rice and Wexler (1996) have shown that difficulties with inflections, particularly tense-marking suffixes, are a clinical marker of SLI as is difficulty acquiring bound morphemes in oral language (Swisher & Snow, 1994). More recently, the focus has extended to derivations in the written orthography with 9- to 10-year-old children with SLI who demonstrate significant challenges in spelling derivational versus inflectional morphemes (Critten et al., 2014).

The focus on derivational morphology, written orthography, and older students sets up our current study. Derivational relationships (i.e., when morphemes are combined within words to change semantic or grammatical meaning; *fearful*) compared to inflections (i.e., changing tense, number, gender, or possession; *running*) play an increasingly important role in academic language by middle school (Anglin et al., 1993; Nagy & Anderson, 1984; Nagy & Townsend, 2012). Additionally, written academic language conveys morphological relationships in ways that oral language does not. This is due to the nature of the English orthography, where the spelling of the root word (*magic, magician*) or affix (*jump, jumped*) tends to be retained even when the pronunciation changes (Spencer et al., 2015; Venezky, 1999). This means that the morphological link between *know* and *knowledge* is conveyed via the way *knowledge* is spelled but not pronounced. Taking a developmental lens, middle schoolers are reading texts that have large numbers of morphologically complex words (Nagy &

Anderson, 1984), which primes them to attend to the morphophonemic nature of the English orthography. As such, our study extends the typical way that morphological knowledge is considered by broadening the conceptualization to include an emphasis on derivations versus inflections, and attending to the morphophonemic nature of the English orthography.

Different Supports for Students

In broadening our definition of morphological knowledge, another important extension involves our consideration of the type of student who might be differentially effective at applying morphological strengths and weaknesses to reading comprehension efforts, with our focus being on students who struggle in reading vocabulary. Here, we are purposefully bringing ways these constructs are considered in the general education literature to bridge ways of thinking within the more special education literature. Those who work with special education populations tend to use many assessments to get very specific profiles. Here, one would assess word reading and vocabulary separately. In contrast, we follow the developmental, practical, and theoretical arguments of many who, like Kieffer and Lesaux (2012), suggest using a reading vocabulary measure. Here, students are not assessed for whether they can pronounce a word, but rather whether they can access the meaning of a word provided to them in print. This is different from sight word measures or decoding measures in which vocabulary is not measured and where the emphasis is on pronunciation versus meaning.

In the current study, we argue that it is important to consider reading vocabulary, which may simultaneously assess vocabulary and word reading because there is strong precedence for accounting for written vocabulary linked to reading comprehension. For example, Pearson et al. (2007) note that when designing assessments, "words that characterize the vocabulary of mature language users and [are represented in] written rather than oral language" (p. 293) are key criteria for large assessments such as the National Assessment of Educational Progress. This is because words in written discourse tend to be more formal than those in oral discourse. Although these words can be assessed orally, it is important to note that typical oral language measures often either rely on pictorial representations, working memory, or production of language by participants to describe complex definitions or degrees of meaning. These types of measures can be problematic as they add confounds into the assessment of vocabulary knowledge; for example, language is confounded with producing definitions, and pictorial tasks do not readily measure the nuances of complex words that cannot be visually represented. As Kieffer and Lesaux (2012) indicate, "many of the word meanings that are important to reading comprehension in upper elementary and middle school grades are abstract representations of processes and relationships, such as regulation or analysis…that appear more frequently in written text than oral conversation and cannot be easily represented with pictures" (p. 354).

These noted challenges of vocabulary measurement are consistent with the growing body of research that emphasizes the semantic difficulty of academic language (Nagy & Townsend, 2012). As Nagy and Townsend state, "Academic language is specialized because it needs to be able to convey abstract, technical, and nuanced ideas and phenomena that are not typically examined in settings that are characterized by social and/or casual conversation" (p. 92). There are core skills involved in deciphering academic language (see Uccelli et al., 2015; Phillips Galloway & Uccelli, 2019), and these move beyond typical views of word reading and vocabulary to acknowledge the additional semantic processing demands of academic language, including determining the meaning of morphologically complex words within dense academic phrases. This work suggests that while students with specific profiles such as students with disabilities and English language learners (ELL) would likely have difficulties with reading vocabulary, so would the broader group of students that struggle with the semantic nuances of academic language. Although academic language is not the same as reading vocabulary, it is another reason to conduct research with a focus beyond typical conceptualizations of oral vocabulary.

In addition to the stated characteristics of written language, there are important developmental reasons for considering reading vocabulary as well. By middle school, word reading plays less of a role in reading comprehension, mostly because the basics of decoding have been largely mastered, whereas language and, in particular, learning the nuanced meanings of the words being read are still being learned. For example, Foorman et al. (2018) showed that "above grade 4, decoding had no unique contribution to reading comprehension" (p. 16). This suggests that, for this population, it is less important to separate decoding from vocabulary than it is to assess how students are using vocabulary in their reading of texts, which again have a more formal and academic discourse. Other researchers have confirmed this decrease in the importance of decoding at this age. For example, García and Cain (2014) examined 110 studies of 42,891 readers and found that, around age 10 years, which is the typical age of children entering fifth grade in the United States, the correlation between decoding and comprehension decreases. Lastly, from a practical view, often the assessments that practitioners use involve reading vocabulary because this tends to be what is assessed at scale as resource limits assessing via oral individual measures (Kieffer & Lesaux, 2012). Hence, better understanding of students with reading vocabulary difficulties is important.

The current study focuses on students with reading vocabulary difficulties versus those students with specific clinical diagnoses. This focus is aligned with our goal of bridging general educational research with research focusing on special education populations. Our decision follows the trend toward response to intervention (Fuchs & Fuchs, 1998; Gersten & Dimino, 2006), also currently termed

Multi-Tiered Systems of Support, where practitioners intervene with students who are having difficulty regardless of diagnosis (and as part of the diagnosis process). Here, teachers likely have data (i.e., reading vocabulary measures that can be administered at scale, such as the vocabulary section of the Measures of Academic Progress [MAP] or Group Reading Assessment and Diagnostic Evaluation or other standardized assessments) that indicate a struggle in reading vocabulary and a need for support. Potentially, the results of our study can provide guidance in such scenarios.

In reviewing the special education literature, we note two big understandings. The first is that children with reading and language disabilities have lower levels of morphological knowledge in general (Casalis et al., 2004; Fowler & Liberman, 1995; Rubin et al., 1991; Siegel, 2008) and, more specifically, that children with reading disabilities compared to those with other diagnoses such as math disabilities or attention-deficit disorder perform worse on morphological knowledge measures (Shankweiler et al., 1995). Clinical work like that by Joanisse et al. (2000) suggests that different types of readers with dyslexia have additional difficulty with morphological knowledge tasks. For example, children with phonological dyslexia (i.e., poor nonword reading and phoneme deletion performance) and developmental language impairment (i.e., poor word structure and vocabulary performance) show greater difficulty than children with globally delayed dyslexia (i.e., average nonword reading and phoneme deletion). The type of morphological tasks that are difficult vary by profile. Students with dyslexia tend to perform better on oral measures of morphological knowledge (Casalis et al., 2004), whereas children with SLI show difficulty in oral morphological knowledge measures, highlighting their challenges with tense-marking suffixes and bound morphemes in oral language (Rice & Wexler, 1996). Hence, students with difficulties have a hard time in general with morphological knowledge, but some types of students struggle in particular, and some tasks are particularly hard for some types of students.

At the same time, this research base from special education indicates supports of morphological knowledge for students with disabilities. For example, Casalis et al. (2004) showed that upper elementary children with dyslexia performed better compared to a reading age control group on producing words that belonged to the same morphological family. Studying teenagers, Elbro and Arnbak (1996) showed that, although students with dyslexia performed worse on general word reading measures compared with younger students, they read morphologically transparent words faster than controls. Interestingly, Elbro and Arnbak also showed that students with dyslexia read more accurately and faster when presented text morpheme-by-morpheme rather than syllable-by-syllable, whereas control students showed no such differences. In fact, adolescents with dyslexia read equally well when presented with morphemes as when presented with words, whereas control students read better when reading words. With regard to reading comprehension, Gilbert et al. (2014) showed that, even when fifth-grade poor word readers had less morphological knowledge than stronger readers, they still seem to use that information to support reading comprehension. These studies of clinical populations suggest that there are likely ways that students with limited reading vocabulary knowledge use their morphological knowledge more or less effectively in supporting reading comprehension.

Here, we share a note about multilingual learners, or in particular children who are learning English, the dominant language of society, as their second (L2) or even third language. These students tend to be students for whom reading vocabulary would be a challenge because research suggests that they master word reading relatively quickly but have lower levels of L2 vocabulary knowledge (August & Shanahan, 2006). This is another area where there is a plethora of research on the supportive role of morphological knowledge and its instruction in building vocabulary and reading comprehension (Goodwin et al., 2015; Kieffer & Lesaux, 2008, 2012; Proctor et al., 2020; Siegel, 2008). This is likely because morphological knowledge gives these learners ways to apply first language knowledge to learning English (Lam et al., 2020) as well as to figure out unknown words (Pacheco & Goodwin, 2013). While these studies confirm the important role of morphological knowledge, they also suggest a similar makeup (i.e., dimensionality) albeit lower levels of morphological knowledge and vocabulary for these students (Kieffer & Lesaux, 2012). Importantly, the difference in morphological knowledge was smaller between fluent English students and students learning English as an L2 compared to vocabulary breadth and contextual sensitivity, again suggesting morphology may play a compensatory role.

Multidimensional Morphological Assessment and Reading Comprehension

In order to examine morphology's full role in reading comprehension, we use a multidimensional morphological knowledge assessment. This is because studies of dimensionality of morphological knowledge (Goodwin et al., 2017, 2020) and studies of models exploring the differing contributions of morphological knowledge aspects (Lam et al., 2020; Levesque et al., 2017, 2019) both indicate morphological knowledge is multidimensional. Modeling the multidimensionality of morphological knowledge is important because the relationship between morphological knowledge and reading comprehension depends on the type of morphological knowledge being measured. For example, Levesque et al. (2019) recently showed that morphological analysis made a significant contribution to growth in reading comprehension, whereas morphological awareness did not when controlling for prior performance. In a different study, Levesque et al. (2017) showed that morphological awareness contributed to different mediators, including other morphological skills, which then supported reading comprehension. Specifically, morphological awareness

supported reading morphologically complex words, which then supported word reading that supported reading comprehension. Morphological awareness also supported morphological analysis, which then supported reading comprehension. In another example, Goodwin et al. (2017) showed that a general factor of morphological knowledge (created via a bifactor model involving an overlap of seven morphological knowledge tasks) and the morphological processing factor (created from a meaning processing task) contributed to reading comprehension. Hence, the specific aspect of morphological knowledge, be it morphological awareness, morphological analysis, and/or morphological processing, appears to be an important factor that needs to be considered when unraveling how morphological knowledge and vocabulary are related to reading comprehension. The format of task (i.e., multiple choice, true/false, open response) seems less important as Spencer et al. (2015) provided evidence of a unidimensional construct of morphological knowledge when exploring differences related to a format like oral versus written tasks or multiple-choice versus oral tasks.

Overall, in order to explore the complexity of morphological strengths and weaknesses, we capitalize on the modeling framework from Goodwin et al. (2018) and use Monster, P.I. (Goodwin et al., 2020), a standardized language assessment developed by the authors for middle schoolers. This is the only standardized test that we know of that assesses morphological knowledge in a multidimensional manner. In this test, we utilize a bifactor model to identify four teachable morphological skills that are separate from task demands and include (a) participant's ability to identify of units of meaning (i.e., morphological awareness), (b) use of syntactic information in suffixes to shift words' parts of speech, (c) use of semantic information within morphemes to support meaning (i.e., morphological analysis), and (d) use of orthographic and phonological information conveyed by morphemes to support word reading and spelling. This assessment has shown to be reliable and valid based on development work with more than 13,000 fifth through eighth graders (Goodwin et al., 2020).

The Current Study

The current study investigates how different types of readers, including those with limited reading vocabulary, apply different morphological skills to reading comprehension. The current study adds to the literature in multiple ways. First, we consider morphological knowledge as multidimensional and potentially differentially effective in supporting reading comprehension for different types of students. Second, we extend the focus from how students use morphological clues in oral language only and now consider use of cues conveyed via the written morphophonemic orthography of English. Third, we consider students with limited reading vocabulary. Fourth, we assess student's morphological knowledge via a computer-adaptive assessment that is conveyed as a game, which we think is important as students with clinical difficulties get assessed often and such assessments take up instructional time and can foster a lack of engagement. Our research question is as follows: How do different morphological skills support or hinder reading comprehension for students with typical development as compared to students with limited reading vocabulary?

Method

Participants

Participants were 1,140 fifth through eighth graders (N = 447 fifth graders, 258 sixth graders, 198 seventh graders, and 237 eighth graders) from an urban district in the southeastern United States. The sample was diverse, with 53% of the sample as female; 43% of the sample were White, 31% were Black, 22% were Latinx, and 4% were Asian; 29% of students were eligible of free or reduced price lunch; and 5% of students were identified as an ELL within the past 2 years at the time of participation of the study. With that said, based on district data, these students spoke 30 different home languages, with English (N = 906) being the predominant language but then Spanish (N = 256), Arabic (N = 65) Amharic (N = 22), Vietnamese (N = 11), and Kurdish (N = 11) being the main languages spoken. A total of 79 students received special education supports, which was reported by the district in hours with a mean of 9.41 hr of services (SD = 10.38). We included students with special needs and ELLs in our sample because of our emphasis on building a broader picture.[1] Of our full sample, 184 (i.e., 16% of the sample) showed limited reading vocabulary knowledge as defined as achieving a standard score below 85 on the Gates Reading Vocabulary assessment (MacGinitie et al., 2000, see description in the Measures section). This sample with limited reading vocabulary was 47% female; 27% were White, 38% Black, 30% Latinx, and 5% Asian; 55% were eligible for free or reduced price lunch; and 27% were identified as an ELL.

Measures

Morphological Knowledge

Following our theoretical framework, morphological knowledge was assessed via the morphology measure included within the Monster, P.I. assessment. This measure is a computer-adaptive, app-based, gamified assessment that measures language skills, specifically morphology, vocabulary, and syntax skills, for fifth to eighth graders. The assessment is delivered as a game where a mischievous monster destroys parts of a city, including a school, museum, library, sports arena, and amusement park. Students are tasked with solving puzzles (i.e., items on the assessment) to earn clues to identify and catch the monster to save the city! Further information can be found at

[1]Also, prior research suggests ELLs would have reading vocabulary challenges (i.e., good word reading but low L2 vocabulary knowledge) and similar makeup (i.e., dimensionality) of vocabulary and morphological knowledge (Kieffer & Lesaux, 2012).

https:/www.worddetectives.com and at Goodwin et al. (2020, in press) as well as validation information at Goodwin et al. (2019). Seven tasks are used to provide scores for four morphological skills (see the following sections and Table 1 for examples of each task and reliabilities for each skill). Note that we provide reliabilities by skill in Table 1 rather than by task because scores for skills were used rather than task scores in our analysis. Dichotomous scoring (correct = 1, incorrect = 0) was completed by the computer. Questions were presented in print, although pilot work showed no significant differences in performance when questions were presented in print alone versus read aloud (see Goodwin et al., 2019).

Skill 1: morphological awareness. The ability to reflect upon and manipulate morphemes (i.e., identify units of meaning) was assessed via two tasks: Odd Man Out and Meaning Puzzles tasks. For the Odd Man Out task, participants identified units of meaning within words by analyzing three similar-looking words to determine which of the words did not fit morphologically. Adapted from Ku and Anderson (2003), words sets differed in whether the two (of three) words overlapped in suffixes, prefixes, or root words and whether the relationships were transparent or opaque. For the Meaning Puzzles task, participants saw a morphologically complex target word and then selected the answer choice that shared a morpheme with the target word. Distractors included a visual overlap (e.g., *fast, strong, as*) with the target word (e.g., *astronomy*), but only the correct answer (e.g., *astronaut*) had morphological overlap (see Table 1). This task was adapted from intervention work (Goodwin, 2016) and piloted (Pacheco & Goodwin, 2013).

Skill 2: use of syntactic morphological knowledge. Knowledge of how morphemes shift words' parts of speech was assessed via two tasks: Real Word Suffix and Making It Fit tasks. The Real Word Suffix task was adapted from measures often used in the literature (i.e., suffix tests; Tyler & Nagy, 1989) and required students to use syntactic information contained within suffixes to choose, from four choices, the word that best fits the sentence. Each choice contained the same root but had different suffixes (e.g., *historic, historian, history, historically*). The Making It Fit task is similar to production tasks often used in the literature (i.e., Carlisle, 1988). In this task, students were provided with a base word and a sentence with a blank. Students then had to adapt the base word to the syntactically appropriate form to complete the sentence (see Table 1).

Skill 3: use of semantic morphological knowledge. Participant's ability to use the semantic information in morphemes to figure out the meanings of words was assessed via the Word Detectives task. Students read a sentence that contained an underlined morphologically complex word in a sentence with little context. They then identified the meaning of the word with answer choices by using their

Table 1. Skills and measures described with examples.

No.	Skill or task name	Description	Example item
Skill 1: Morphological awareness; marginal reliability = 0.90			
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: Use of syntactic morphological knowledge, which considers how suffixes shift words' parts of speech; marginal reliability = 0.93			
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.
Skill 3: Use of semantic morphological knowledge, which considers using units of meaning to figure out the meanings of words (i.e., morphological word-solving); marginal reliability = 0.70			
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, and (d) ordered spatially.
Skill 4: Use of orthographic and phonological morphological knowledge, which is used to support word reading and spelling; marginal reliability = 0.92			
6	Morphological Word Reading	Students identified the correct pronunciation of a morphologically complex word.	Students heard three pronunciations of nationalistic and had to choose the one that was correct.
7	Morphological Spelling	Students spelled words that have multiple units of meaning	1. Knowledge 2. Leverage

Note. Marginal reliability (Sireci et al., 1991) was estimated with $\rho = \frac{\sigma_\theta^2 - \sigma_{\varepsilon*}^2}{\sigma_\theta^2}$, where σ_θ^2 is the variance of ability score for the normative sample and $\sigma_{\varepsilon*}^2$ is the mean-squared error.

knowledge about the morphological makeup of the word. This task is similar to other reading vocabulary tasks, although the target words were chosen because they could be morphologically analyzed similar to Anglin et al. (1993) and Tyler and Nagy (1989). To add motivation, the task was framed as a detective activity, with students using clues in the word to figure out the target word's meaning.

Skill 4: use of phonological/orthographic morphological knowledge. These sources of morphological knowledge were assessed via two tasks: Morphological Word Reading and Morphological Spelling tasks. For the Morphological Word Reading task, the use of phonological information conveyed by morphemes was assessed. Students identified the correct pronunciation of morphologically complex words from three pronunciations, including two distractors. Distractors were the mistakes most often made while reading the targeted words aloud in pilot data collection with middle schoolers. For the Morphological Spelling task, participants used the orthographic information within morphemes to support spelling morphologically complex words. Adapted from Carlisle (1988) and Nunes et al. (2012), students listened using headphones and then spelled the word heard using the iPad's keyboard. The words were presented one time, but students could push a button for the word to be repeated.

Reading Comprehension

MAP Reading (Northwest Evaluation Association, 2014) assessed reading comprehension via a multiple-choice, reliable (.90–.95), standardized computer-adaptive test that is nationally normed and designed to assess achievement and growth in reading. Scores are provided in Rasch units that allow for comparisons across grades. Participants read texts and answered comprehension questions and also matched sentences to pictures or diagrams. According to guidelines, students tend to complete 25–30 items that are at their level, which involves 20–40 min of testing time (Merino & Beckman, 2010).

Reading Vocabulary

Gates–MacGinitie Reading Vocabulary Assessment (MacGinitie et al., 2000) was used to assess participant's lexical access for words presented in print as a way of identifying students with limited reading vocabulary. For this assessment, students answered 45 multiple-choice items where they read an underlined word within a phrase and choose the word or phrase that conveyed a similar meaning. Form S of the Level 5 through 8 version of the assessment was used. This task is used extensively in research with strong reliability and validity. Extended scale scores were used.

As a way to determine overlap between the Gates–MacGinitie Reading Vocabulary Assessment and assessments of oral vocabulary, we explored correlations with Monster, P.I. For this sample, scores correlated significantly and moderately ($r = .61$) with performance on the Monster, P.I. vocabulary assessment where items were shown in print and read aloud. Note that the Monster, P.I. vocabulary assessment is multidimensional in nature (i.e., considers definitions, synonyms, antonyms, analogies, and polysemy), whereas this Gates measure assesses reading vocabulary more unidimensionally, hence accounting for some of the potential difference. We chose to use the standardized measure for this study as it is more often used in research and practice.

Procedures and Data Analysis Plan

The data for this study are part of a larger 3-year study (Goodwin et al., 2019) with the current study involving data from Year 3 where students took the computer-adaptive (CAT) version of Monster, P.I. in one session as well as the standardized vocabulary assessment. The CAT allows students to take the subsample of items that best align with their ability level, hence obtaining a reliable score with fewer items. Then, an additional set of fixed items were completed in a second session (used to extend the CAT's item pool, although not used in the current study). We analyze data from the CAT session. For both sessions, trained research assistants provided iPads and instructions for participants, who completed the assessment and then were allowed to play additional Monster, P.I. games. Data were also collected from the district regarding standardized reading. A two-step multiple regression analysis was used to test for the relation between morphology skills and standardized Reading Comprehension (MAP). In the first step of modeling, the four morphological knowledge skill scores used were entered into a simultaneous prediction of reading comprehension to examine the unique effects of each skill and the overall explanatory power of the morphology scores via an R^2 statistic. The second step was to include the dichotomous indicator of limited reading vocabulary skills (i.e., < standard score of 85) as a main effect predictor of Reading Comprehension as well as interactions between limited reading vocabulary and each of the morphological knowledge skills to understand the extent to which limited reading vocabulary moderated the relation between morphology and reading comprehension. Note that, in our larger validation work, we considered potential developmental differences in morphological knowledge, but our findings of a consistent best fit for the multidimensional model used in Monster, P.I. across grade levels led us to consider this sample of students as a single general young adolescent group (Goodwin et al., 2019).

Results

We started by considering missing data. Complete data were available for morphological knowledge skills and the reading vocabulary scores. Eleven percent of the cases were missing data on the Reading Comprehension score ($N = 129$); Little's test of data missing completely at random resulted in a fail to reject, $\chi^2(5) = 37.58$, $p < .001$, suggesting the mechanism for missingness did not meet this threshold. The data were reviewed for problematic missing data patterns, and ultimately, the data were judged to be

missing at random. Full information maximum likelihood was used in the multiple regression models via the lavaan package (Rosseel, 2012) in R software.

Descriptive statistics and correlations are reported in Table 2. The full sample performed within the normal range on each morphological knowledge skill as a developmental scale is used that had a mean of 500 and an *SD* of 100. Correlations between the morphological knowledge skills and reading vocabulary ranged from $r = .56$ to .70, and correlations between the morphological knowledge skills and Reading Comprehension scores ranged from $r = .55$ to .69. Correlations between the morphological knowledge skills themselves ranged from .53 to .67, with the largest correlation being between Skill 1 (Morphological Awareness) and Skill 2 (Syntactic Morphological Knowledge) and the smallest correlation being between Skill 3 (Semantic Morphological Knowledge) and Skill 4 (Phonological/Orthographic Morphological Knowledge). The limited reading vocabulary sample performed much lower than the full sample average on all reported measures (see Table 2).

We were interested in how the different morphological knowledge skills (Morphological Awareness, Syntactic Morphological Knowledge, Semantic Morphological Knowledge, and Phonological/Orthographic Morphological Knowledge) supported or hindered reading comprehension for students with limited reading vocabulary compared to students with reading vocabulary scores in the typical range. Hence, we explored how each skill predicted Reading Comprehension. Results of the multiple regression models are reported in Table 3. We started by exploring the link between each morphological skill and Reading Comprehension for the sample as a whole. The main effects model results showed that all four morphological knowledge skills significantly and substantively explained individual differences in Reading Comprehension scores. The standardized, partial coefficient of .40 showed that Skill 2 (Syntactic Morphological Knowledge) had the strongest predictive relation to Reading Comprehension followed by .17 for Skills 1 (Morphological Awareness) and 4 (Phonological/Orthographic Morphological Knowledge) and .13 for Skill 3 (Semantic Morphological Knowledge). The combination of morphological knowledge skills explained 54% of the variance in Reading Comprehension, suggesting that morphological knowledge plays a key role in reading comprehension for the general sample.

We then explored differences for students who were classified as having limited reading vocabulary scores (i.e., standard score of 85 or below). Overall, results suggested that these students had lower Reading Comprehension scores by approximately 18 points ($p = .045$). Also, the relation between morphological skills and Reading Comprehension was different for these students. Specifically, status as a student with limited reading vocabulary scores moderated the relationship between Reading Comprehension and Skills 2 (Syntactic Morphological Knowledge, 0.04, $p = .017$), 3 (Semantic Morphological Knowledge, −0.06, $p < .001$), and 4 (Phonological/Orthographic Morphological Knowledge, 0.03, $p = .012$). No significant interaction between limited reading vocabulary and Skill 1 (Morphological Awareness) was observed (−0.00, $p = .984$).

Figure 1 displays the nature of the interactions for each of the terms in Table 3. Note that, when considering Skill 1 (Morphological Awareness; see Figure 1, upper left), the confidence intervals for simple slope lines for limited reading vocabulary and typical vocabulary students were overlapping, reflecting the lack of significant moderation from Table 3. The interaction between Skill 2 (Syntactic Morphological Knowledge) and reading vocabulary in Figure 1 (upper right) shows that, at low levels of morphological knowledge Skill 2 (i.e., −1 *SD* below in Syntactic Morphological Knowledge), typical students have higher estimated Reading Comprehension scores compared to students with limited reading vocabulary. In contrast, at higher levels of Skill 2 (i.e., +1 *SD* above in Syntactic Morphological Knowledge), there were no estimated differences in Reading Comprehension scores between reading vocabulary groups. This suggests that students with higher Skill 2 (Syntactic Morphological Knowledge) scores seemed to use that strength to support their reading comprehension, "catching up" with typical peers. An identical trend was observed for Skill 4 (Phonological/Orthographic Morphological Knowledge; see Figure 1, lower right), with higher estimated Reading Comprehension scores for typical students versus students with low reading vocabulary scores when Skill 4 (Phonological/Orthographic Morphological Knowledge) was less than at least 1 *SD*: again, the higher

Table 2. Means, standard deviations, and correlations.

Variable	*M*	*SD*	1	2	3	4	5
1. Reading Vocabulary	521.84 (464.60)	39.84 (17.70)	1.00				
2. Reading Comprehension	218.85 (199.66)	15.79 (16.22)	.79**	1.00			
3. Skill 1: Morphological Awareness	489.34 (430.88)	78.50 (55.29)	.62**	.60**	1.00		
4. Skill 2: Syntactic Knowledge	496.80 (420.91)	79.61 (59.63)	.70**	.69**	.67**	1.00	
5. Skill 3: Semantic Knowledge	486.69 (443.92)	72.62 (58.56)	.61**	.55**	.56**	.59**	1.00
6. Skill 4: Phonological & Orthographic Knowledge	493.55 (433.74)	80.21 (79.28)	.56**	.57**	.55**	.62**	.53**

Note. Values in parentheses are for the limited vocabulary subsample.

**Indicates $p < .01$.

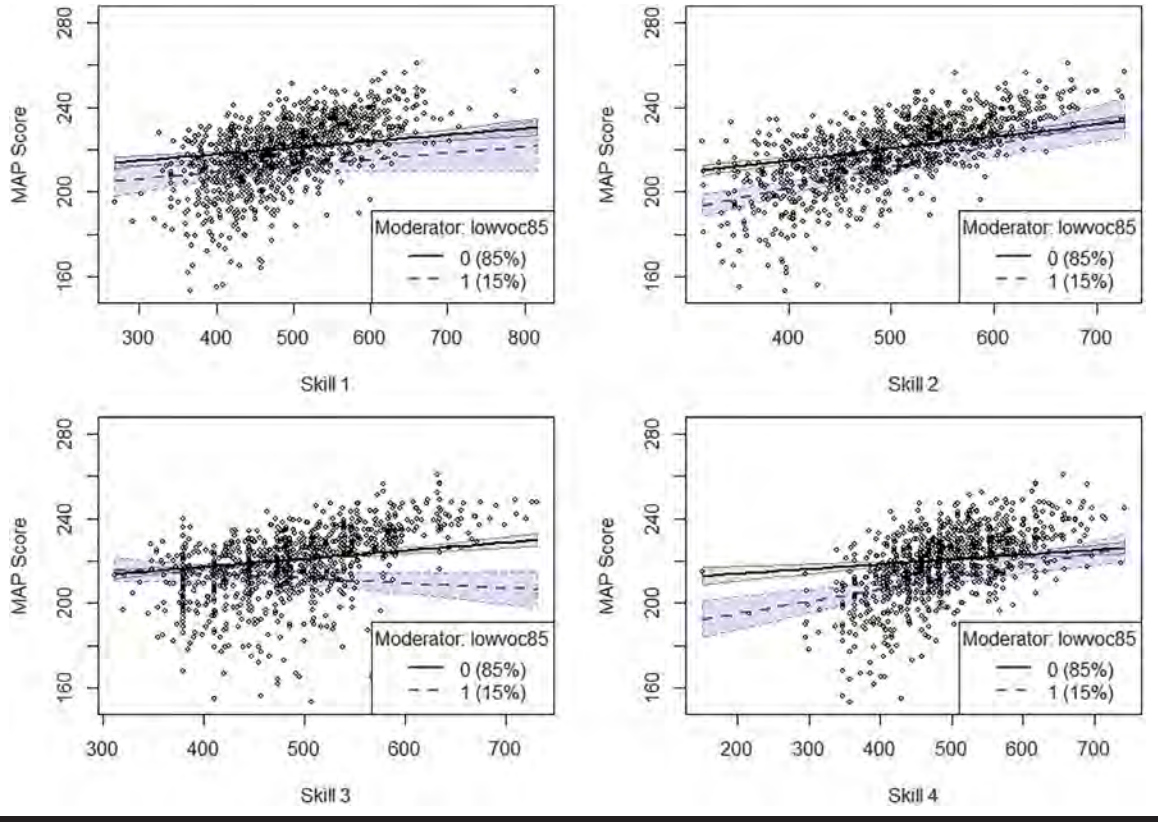
Table 3. Morphology main effect and interaction models.

	Main effects model					Interaction effects model				
Predictors	**Estimates**	**std. beta**	**CI**	**Standardized CI**	***p***	**Estimates**	**std. beta**	**CI**	**Standardized CI**	***p***
Intercept	132.71		[127.55, 137.86]		**< .001**	147.35		[141.74, 152.95]		**< .001**
Skill 1	0.03	0.17	[0.02, 0.05]	[0.11, 0.23]	**< .001**	0.03	0.15	[0.02, 0.04]	[0.09, 0.21]	**< .001**
Skill 2	0.08	0.40	[0.07, 0.09]	[0.33, 0.46]	**< .001**	0.06	0.28	[0.04, 0.07]	[0.22, 0.35]	**< .001**
Skill 3	0.03	0.13	[0.02, 0.04]	[0.08, 0.19]	**< .001**	0.04	0.18	[0.03, 0.05]	[0.12, 0.24]	**< .001**
Skill 4	0.03	0.17	[0.02, 0.04]	[0.11, 0.22]	**< .001**	0.02	0.11	[0.01, 0.03]	[0.05, 0.17]	**< .001**
Low Vocab						–17.92	–0.40	[–35.42, –0.41]	[–0.80, –0.01]	**.045**
Skill 1 × Low Vocab						–0.00	–0.00	[–0.04, 0.04]	[–0.36, 0.35]	.984
Skill 2 × Low Vocab						0.04	0.43	[0.01, 0.08]	[0.08, 0.78]	**.017**
Skill 3 × Low Vocab						–0.06	–0.62	[–0.09, –0.03]	[–0.96, –0.28]	**< .001**
Skill 4 × Low Vocab						0.03	0.35	[0.01, 0.06]	[0.08, 0.62]	**.012**
Observations	1011					1011				
R^2/adjusted R^2	0.539/0.537					0.599/0.595				

Note. CI = confidence interval.

the Skill 4 (Phonological/Orthographic Morphological Knowledge) score, the closer the student with limited reading vocabulary scored to typical students. The opposite finding was true for Skill 3 (Semantic Morphological Knowledge; see Figure 1, lower left) whereby typical students had higher estimated Reading Comprehension scores compared to students with limited reading vocabulary when Skill 3 (Semantic Morphological Knowledge) scores were at least

Figure 1. Graphed interactions between limited vocabulary (lowvoc85 = 1) and typical vocabulary (lowvoc85 = 0) with morphology Skill 1 (upper left), Skill 2 (upper right), Skill 3 (lower left), and Skill 4 (lower right). MAP = Measures of Academic Progress.



1 *SD* above the mean; no differences in Reading Comprehension between the reading vocabulary groups were observed when Skill 3 (Semantic Morphological Knowledge) scores were at least 1 *SD* below the mean. The inclusion of reading vocabulary and the interaction terms resulted in 60% of the variance explained in Reading Comprehension, suggesting meaningful differences were observed.

Discussion

The role of morphological knowledge has been increasingly explored in the research literature. This study adds to the literature by deepening the understanding of how different derivational morphological skills support or hinder reading comprehension and then exploring differences for students with low levels of reading vocabulary. This can help educators and researchers better understand the role of morphological knowledge in reading comprehension for different groups of students. Our key findings are that different morphological knowledge skills support reading comprehension for typically achieving students (i.e., students with average and high levels of reading vocabulary) with students applying morphological awareness as well as using the syntactic, semantic, and phonological/orthographic morphological information conveyed by morphemes to support reading comprehension. In contrast, while morphological knowledge was shown to be supportive of reading comprehension for students with limited reading vocabulary, there are certain morphological skills that are particularly supportive and others that seems to hinder reading comprehension efforts.

Specifically, students with limited reading vocabulary seemed to apply the syntactic, phonological, and orthographic information within morphemes, but struggled when applying the semantic information in morphemes to reading comprehension endeavors. This was shown by how the relation between Skills 2 (Syntactic Morphological Knowledge) and 4 (Phonological/Orthographic Morphological Knowledge) and reading comprehension was moderated by limited reading vocabulary in a positive manner. The relationship between performance on Skill 3 (Semantic Morphological Knowledge) and reading comprehension was also moderated by reading vocabulary, but in a negative direction, indicating that even students with limited reading vocabulary who performed well on Skill 3 (Semantic Morphological Knowledge) were unable to effectively apply that knowledge to reading comprehension endeavors. The role of Skill 1 (Morphological Awareness), which involved identification of units of meaning, in supporting reading comprehension was not moderated by reading vocabulary, which means that limited reading vocabulary students were similarly able to apply this skill to reading comprehension as students with typically developing reading vocabulary.

To fit these findings in the literature, we return to the theory and research described in the literature review. Our study provides further evidence for the multidimensionality of morphological knowledge and the idea that different sources and ways of processing of morphological knowledge are differentially supportive of reading comprehension. It also confirms work from research focusing on special education indicating that certain morphological skills are particularly difficult while others play a compensatory role in reading comprehension for readers of certain reading and language profiles. Overall, we found that students with limited reading vocabulary seemed to apply morphological awareness (i.e., Skill 1) similarly to students with typical reading vocabulary scores in support of reading comprehension. This confirms the general support of conscious consideration of word structure (i.e., what is typically termed "morphological awareness") to students of all types, which was indicated by the larger literature (see earlier literature review).

In terms of morphological knowledge strengths and weaknesses, whereas the literature suggested difficulty with suffix tasks (i.e., Skill 2) for students with SLI, our study indicates that use of syntactical information in suffixes can be particularly helpful in supporting reading comprehension for students with limited reading vocabulary, a subgroup of students that may be part of the SLI population at large. Similar to the findings with students with dyslexia, we also found that use of orthographic and phonological information conveyed by morphemes played a compensatory role in supporting reading comprehension, meaning that students with limited reading vocabulary seemed to rely on this skill more than those with higher levels of reading vocabulary. Lastly, use of the semantic information in morphemes was particularly problematic for students with limited reading vocabulary. This is different from what the literature might suggest for students traditionally thought as having limited reading vocabulary, such as ELLs, because the literature indicates the semantic supports of morphemes play an important role in supporting vocabulary and reading comprehension for these students. It may be that students with limited reading vocabulary struggle with vocabulary because of their difficulty in applying semantic information from morphemes to word learning, although future research is needed to unravel this further. Overall, our findings help build deeper understandings of the morphological strengths and weaknesses of students with limited reading vocabulary, which both fits with and is different from what would be indicated in the existing research literature.

In terms of linking to the general education literature, our findings also align and add to understandings. First, Levesque et al. (2017) indicates directionality, showing that morphological awareness (similar to Skill 1) supported both morphological word reading (similar to Skill 4) and morphological analysis (similar to Skill 3), which then supported reading comprehension. Although our study does not explore directionality, we do show the additive contributions of each morphological skill, suggesting that each skill makes a unique contribution. This is important because it indicates that, to explore the full role of morphological knowledge in reading comprehension, one must consider morphological knowledge as multidimensional and include considerations of morphological awareness,

syntactic morphological knowledge, semantic morphological knowledge, and phonological/orthographic morphological knowledge. The current research supports to consider these four key morphological skills, the three explored by the Levesque et al. study, and the additional use of the syntactic information in suffixes, which was found to be important to reading comprehension in Lam et al. (2020). It is important to note that, by using the Monster, P.I. assessment, we were able to explore the role of these morphological skills apart from task demands. This is different from each of the studies reviewed earlier, which used a single task to assess that morphological skill. Monster, P.I. uses a bifactor model to separate construct-relevant variance related to morphological knowledge skills from construct-irrelevant variance that might be specifically related to tasks (Goodwin et al., 2018). Hence, we provide evidence that it is the morphological knowledge skills that are supporting reading comprehension beyond task demands.

Framing these findings in theory, we provide evidence for models of morphological processing and Perfetti's lexical hypothesis. This is because the various skills were set up to identify the role of different types of morphological processing and different morphological content. Our findings of the additive role of each skill suggest that both explicit and implicit morphological processing are important to consider and that the different content within lexical representations of morphemes and morphologically complex words plays a role in reading comprehension.

To further exemplify the educational significance of the important multidimensionality of morphological knowledge in reading vocabulary and reading comprehension, let us consider the following applied example. When encountering *noteworthy* within a text, readers with limited reading vocabulary knowledge would likely, similar to students with typical reading vocabulary, automatically parse the orthographic patterns to access to the morphemic constituents (*note, –worthy*) and their lexical representations. However, in contrast to typical developing students, those with limited reading vocabulary may access the syntactic, phonological, and orthographic sources rather than the semantic information in the morpheme. This would allow the morphological knowledge to only be supportive of some parts of reading such as word reading and understanding the word's syntactic role in a sentence, but not of a key need: determining the word's meaning. It may be that other clues will be needed to support semantic meaning access. Future studies should explore this further and consider whether other meaning-making works such as use of context clues may be more helpful or whether further building of the semantic morphological knowledge component of the lexical representation and additional practice in applying this information to reading comprehension would support students the most.

Limitations

As with any study, it is important to note the limitations of our work. Two main considerations come to mind. First, we prioritized and thus assessed a broad range of morphological knowledge, but did not include many controls often present in the literature such as phonological awareness, word reading, working memory, IQ, or even autoregressors. This was due to the focus of our study, limited testing time, and the age of our participants for whom phonological awareness tends to be closer to mastery (Nagy et al., 2006). With that said, consideration of these controls would help future researchers to more readily differentiate and identify how and if these and related factors uniquely contribute to students' reading comprehension. Second, for this study, we explored differences between our general participant sample and the group who demonstrated limited reading vocabulary scores on a standardized reading vocabulary assessment. We purposefully did not sample different clinical populations nor did we use separate oral vocabulary or word reading measures that could effectively unravel vocabulary knowledge from word reading demands. We did this for a few reasons, including our interest in the written orthography and our focus on conducting educationally relevant research with testing typical of middle school students. An important next step for future research, however, would be to continue to unravel oral and written vocabulary and reading differences across and within clinical populations.

Links to Instruction

Our findings have important implications for educational instruction. First, assessment of the multidimensional nature of morphological knowledge is important. Our ability to test the complex nature of morphological knowledge was critical to understanding middle school student's morphological strengths and weaknesses. At the same time, our study suggests that assessment does not have to be time consuming and boring. The use of a computer-adaptive, gamified assessment provided a timely and ideal framework for assessing morphological knowledge. As reported in Goodwin et al. (2020), students liked the experience and used words like "enjoyed" and "fun" to describe the assessment. Additionally, the assessment is computer adaptive (i.e., CAT), which means that students take items at their level, making the assessment both faster, more accurate, and less frustrating for students with limited language such as those with limited reading vocabulary. This is important because students in general tend to be assessed a lot and students with difficulties are assessed even more, so the combination of efficiency and fun while still providing detailed data (such as the scores for the four morphological knowledge skills) is important to consider.

The most important instructional finding is that students with limited reading vocabulary did indeed use morphological knowledge to support their reading comprehension and demonstrated different morphological strengths and weaknesses. These morphological strengths, such as morphological awareness, syntactic morphological knowledge, and phonological/orthographic morphological

knowledge, should be capitalized upon in instruction. This is consistent with research in the morphological instructional literature as multiple meta-analyses and syntheses (Bowers et al., 2010; Carlisle, 2010; Goodwin & Ahn, 2010, 2013) revealed that interventions featuring morphological knowledge instruction improved reading comprehension outcomes for students with a range of language and literacy difficulties. Bowers et al. (2010) highlighted the many different types of morphological knowledge instruction as helpful for students of varying language and literacy abilities; however, these researchers were not able to identify particularly effective types of morphological instruction. This may be because certain types of morphological knowledge instruction are more effective for certain types of students. For example, with students with limited reading vocabulary, instruction that capitalizes on identification of units of meaning and successful use of syntactic, phonological, and orthographic information in morphemes is likely helpful. Results of our study suggest that these students may need more help in applying semantic morphological information to support their morphological knowledge, which can then support their reading comprehension endeavors.

Instruction such as in Proctor et al. (2020) might provide an example of how morphological knowledge skills might be integrated into more general language and reading comprehension instruction. Proctor and team developed larger units that included strong texts and essential questions. Within this larger structure, they also included instruction on prefixes, suffixes, and root word meanings and then had students create new words by changing affixes. This is an example of how instruction of multiple morphological knowledge skills might occur to support student learning. Future research should continue to focus on which and what combination of skills might be ideal for specific populations of students with and without language and literacy challenges. This is just one example of how an intervention might link to our study findings. We emphasize, however, that this study is not an intervention study, so we hope future research will use these guidelines to design and test what morphological instruction is most effective for different clinical populations of students, including those with limited reading vocabulary.

Summary

Overall, we believe results of the current study help to move the field forward by unraveling the multidimensional nature of morphological knowledge. We demonstrated, with a large sample of middle school students, that different sources and ways of processing of morphological knowledge are differentially supportive of literacy endeavors such as reading comprehension. The specific morphological knowledge skills of morphological awareness, syntactic morphological knowledge, semantic morphological knowledge, and phonological/orthographic morphological knowledge all support overall morphological knowledge that in turn support vocabulary understanding and reading comprehension for students with typical reading vocabulary scores. For students with limited reading vocabulary, the morphological knowledge skills of morphological awareness, syntactic morphological knowledge, and phonological/orthographic morphological knowledge seemed to support reading comprehension. However, these students appeared to struggle when applying the semantic morphological knowledge to reading comprehension endeavors. This more complete understanding provides a foundation upon which to potentially develop differentiated instruction such that morphological knowledge strengths can be leveraged to support academic success for all students.

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