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Comorbidity in Reading Comprehension and Word-Problem Solving Difficulties: Exploring Shared Risk Factors and Their Impact on Language Minority Learners

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Abstract

The purpose of this study was three-fold: to examine unique and shared risk factors of comorbidity for reading comprehension and word-problem solving difficulties, to explore whether language minority (LM) learners are at increased risk for what we refer to as *higher-order comorbidity* (reading comprehension and word-problem solving difficulties), and to examine the profiles of at-risk LM learners compared to at-risk non-LM learners. At-risk (LM *n* = 70; non-LM *n* = 89) and not-at-risk (LM *n* = 44; non-LM *n* = 114) students were evaluated on foundational academic (word reading, calculation), behavioral (behavioral attention), cognitive (working memory, processing speed, nonverbal reasoning), and language (vocabulary, listening comprehension) measures in English. Results indicated listening comprehension was the only shared risk factor for higher-order comorbidity. Further, LM learners were three times more likely to be identified as at-risk compared to non-LM learners. Finally, among at-risk learners, no differences were found on cognitive dimensions by language status, but LM learners had lower reading and listening comprehension skills than non-LM learners, with a relative advantage in behavioral attention. Results have implications for understanding higher-order comorbidity and for developing methods to identify and intervene with higher-order comorbidity among the growing population of LM learners.

Keywords

comorbidity; language; language minority learners; word-problem solving; reading comprehension

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Reading and mathematics difficulties often occur together, affecting approximately 5% of the school-age population (e.g., Landerl & Moll, 2010). Indeed, up to 70% of students with difficulties in one area also show difficulties in the other (Landerl & Moll, 2010). While the rates of comorbidity vary across studies depending on the criterion used, they are higher than what can be expected by chance, even when using the most stringent criterion. Prior studies suggest comorbidity functions as a marker of severity and point to the need to better serve students with comorbid difficulties (Badian, 1999). For example, students with reading and mathematics comorbidity are at increased risk for exhibiting persistent difficulties in both areas (Cirino et al., 2015; Willcutt et al., 2013). Their academic difficulties are more challenging to remediate (Fuchs et al., 2013) and are relatively stable across the elementary grades (Koponen et al., 2018). A better understanding of the underlying mechanisms of reading and mathematics comorbidity as well as student characteristics associated with risk for comorbid difficulties are needed to identify and provide adequate and early support for at-risk students.

Extant research on reading and mathematics comorbid difficulty has been largely focused on foundational or “lower-order” skills, such as word reading and calculations (e.g., Child et al., 2019; Willcutt et al., 2013), with few exceptions (e.g., Cirino et al., 2018). This leaves gaps in our understanding of comorbidity in “higher-order” skills, namely reading comprehension and mathematics word-problem solving, which become increasingly important for academic success over time across subject areas. Further, extant research has been anchored on monolingual English speakers. This limits the extent to which findings can be generalized to the large and growing school-age population of language minority (LM) learners. The term *LM learners* includes (a) students from non-native English-speaking homes, regardless of their English proficiency, such that some LM learners are English-proficient at school entry and (b) students who are in the process of developing English proficiency and receive English Language services (i.e., English learners) (Mancilla-Martinez, 2020). This heterogeneous group accounts for more than 20% of the school-age population (Kids Count Data Center, 2018).

The primary aims of this study were to examine unique and shared risk factors of comorbidity in reading comprehension and word-problem solving (referred to as *higher-order comorbidity*), explore whether LM learners are at increased risk for *higher-order comorbid difficulties*; and examine the profiles of at-risk LM learners compared to at-risk non-LM learners.

Risk Factors of Higher-Order Reading and Mathematics Comorbidity

Overlap Between Reading Comprehension and Word-Problem Solving

Reading comprehension and word-problem solving build on, but also extend, the cognitive resources implicated in word reading and calculation. For successful reading comprehension, students are required to decode words (word reading) as they construct a situation model by activating background knowledge, making inferences, drawing conclusions, and connecting newly acquired information with their existing knowledge (e.g., Kintsch, 1988; Rapp et al., 2007). Similarly, for word-problem solving, although proficient calculation skill is essential, additional forms of cognitive activity are required to solve word problems. This includes decoding and processing text to build a problem model and construct a number sentence before calculating to find the missing information (Fuchs et al., 2020; Kintsch & Greeno, 1985). In this way, word-problem solving is a form of text comprehension (Fuchs et al., 2018; Fuchs et al., 2020).

Given the unique, but also shared, characteristics of reading comprehension and word-problem solving, the multiple deficits model (Pennington, 2006) provides a useful framework for understanding the risk factors that underlie comorbid difficulties. Rather than focusing on a single cognitive cause of an isolated disability, an approach that does not recognize the complexities of comorbidity or various subtypes of learning difficulties, comorbidity is explained by partially overlapping, shared risk factors that underlie both reading and mathematics outcomes within the multiple deficits model. The correlated liability hypothesis further elaborates on the multiple deficits model by positing that risk factors for reading and mathematics are correlated (Willcutt et al., 2013). Thus, comorbid difficulties in reading comprehension and word-problem solving can be characterized by a combination of domain-specific risk factors and domain-general risk factors having a shared role in both domains.

Unique and Shared Risk Factors

When exploring shared risk factors of higher-order comorbidity, we posit that lower-order academic skills exert a direct effect on higher-order skills and partially mediate the relation between domain-general risk factors to higher-order reading and mathematics. The most apparent domain-specific risk factors for higher-order comorbidity are the foundational (lower-order) academic skills: word reading for reading comprehension (García & Cain, 2014) and calculation for word-problem solving (Fuchs et al., 2016). Solid foundations on these lower-order skills in reading and math domains are critical in the development of higher-order skills in each domain as they free up and devote cognitive resources to more complex tasks (Geary et al., 2008; Perfetti, 1988). Moreover, given that word-problem solving requires decoding, a cross-over effect is expected wherein word reading difficulties have a negative impact on word-problem solving (Fuchs et al., 2006).

Taken together, we posit that risk factors for lower-order comorbid difficulties are presumed to be indirectly related to higher-order skills via their relations to the lower-order skills. These include behavioral attention and cognitive processes, such as working memory and processing speed. Moreover, nonverbal reasoning and language may be implicated in higher-order comorbidity given the unique reasoning and language demands for both reading comprehension and word-problem solving. We categorize these potential risk factors of higher-order comorbidity into three domains, behavioral, cognitive, and language; operationalize each risk factor; describe their hypothesized direct or indirect relations to reading comprehension and word-problem solving.

Behavioral Risk.—Behavioral attention is defined as the ability to sustain and allocate attention. Although behavioral attention can be considered under the cognitive risk category, we categorize it as a behavioral risk because it was not a direct child assessment but measured based on teacher observation. Teacher-rated behavioral attention has emerged as a robust predictor of early reading and mathematics development (Duncan et al., 2007) and responsiveness to interventions (Al Otaiba & Fuchs, 2006). For reading comprehension, behavioral attention affects the quality of the mental model constructed directly and indirectly via word reading (Miller et al., 2014). It also influences calculation and word-problem solving, especially for multistep problems (Cirino et al., 2007; Fuchs et al., 2006; Fuchs et al., 2008), thereby making both direct and indirect contributions to word-problem solving.

Cognitive Risk.—Prior studies suggest that processing speed, working memory, and nonverbal reasoning are important cognitive predictors of reading and mathematics (Cirino et al., 2015; 2018). Processing speed, the ability to perform simple, repetitive cognitive tasks efficiently, influences how quickly orthographic information is accessed and numbers are counted (Bull & Johnston, 1997). As such, slow processing speed can create a bottleneck in information processing for word reading and calculation. Indeed, processing speed has been identified as an underlying risk factor for lower-order comorbidity (Anderson & Wagovich, 2010; Willcultt et al., 2008; 2010). Thus, we hypothesized that processing speed is indirectly associated with reading comprehension and word-problem solving.

Working memory refers to the ability to temporarily hold and update information during mental operations (Baddeley, 2002) and is involved in word reading, particularly in decoding multisyllabic words and processing phonological representations of words that are not consolidated in a long-term memory (Compton et al., 2012). It is also essential in reading comprehension because students must process text information while simultaneously activating background knowledge, making inferences about texts, and engaging with comprehension monitoring during reading (e.g., Butterfuss & Kendeou, 2018; Locascio et al., 2010; Swanson & Beebe-Frankenberger, 2004). Working memory is thus hypothesized to be directly and indirectly associated with reading comprehension.

In a similar vein, working memory influences calculation as it requires information (phonological codes of numbers) to be stored temporarily while performing mental operations and working memory deficits may interfere with establishing lexical representations of basic facts in long-term memory (Geary et al., 2007). Further, working memory capacity is related to word-problem solving skills because students rely on working memory when they construct a problem model by registering propositions online as they read the problem, determine a set-building strategy, and execute multi-step calculations (Kintsch & Greeno, 1985; Toll et al., 2011; Van der Sluis, de Jong, & van der Leij, 2007). Taken together, working memory can be expected to exert direct and indirect effects on word-problem solving. Such a mediational path was documented in prior research (Zheng et al., 2011).

Nonverbal reasoning, the ability to complete patterns presented in visual forms, requires students to target essential conceptual information while excluding irrelevant information and is associated with reading comprehension (Kershaw & Schatschneider, 2012) that requires the extraction of main ideas, as well as comparing and contrasting ideas. It is also related to word-problem solving, especially complex word problems (Tolar et al., 2012) or word problems with irrelevant information (Wang et al., 2016), because those problem types require that students identify the most relevant information. As a domain-general cognitive process, nonverbal reasoning is implicated in higher-order academic domains. Thus, we expect it to have direct relations with reading comprehension and word-problem solving.

Language Risk.—Language comprehension, often operationalized as listening comprehension or vocabulary knowledge, is also hypothesized to exert direct effects on reading comprehension and word-problem solving (e.g., Fuchs et al., 2019; Rapp et al., 2007). Although reading comprehension passages typically are substantially longer than mathematics word-problem solving passages, both require comprehension of language. Accordingly, Fuchs and colleagues (2013) found an oral language composite best distinguishes students with higher-order comorbid difficulties in reading comprehension and word-problem solving from those with isolated difficulties. This pattern was absent in lower-order comorbidity in word reading and calculation, suggesting the distinctive role of language in comorbid difficulties of higher-order skills.

Higher-Order Comorbidity and Language Status

The small but growing extant research base on comorbidity has focused almost exclusively on English monolinguals, leaving many questions about the large and growing population of LM learners, who have historically struggled with both academic domains (Fry, 2009). While the rate of comorbidity depends on the criteria used (Cirino et al., 2015), it may also depend on the skills targeted to diagnose reading and mathematics difficulties (e.g., lower- vs. higher-order skills). Prior studies on prevalence have mainly focused on lower-order comorbid difficulties. Little is known about higher-order comorbidity. Even less is known about the extent to which shared risk factors for higher-order comorbidity differentially affect LM students compared to non-LM learners.

A wealth of long-standing research documents the disproportionate reading or mathematics struggles of LM learners, particularly those with limited English proficiency (i.e., English learners), compared to their non-LM learner peers (Fry, 2009). Of course, not all LM learners are formally designated by their schools as English learners (i.e., limited English proficient). More importantly, bilingualism is not a risk factor for compromised academic achievement (Genesee et al., 2004). However, school-based assessments in the U.S. are almost exclusively administered only in English, including for LM learners (Mancilla-Martinez, 2020). Given the hypothesized critical role language plays in higher-order academic skills (Fuchs et al., 2019; Kintsch & Greeno, 1985; Rapp et al., 2007), LM learners may be at increased risk for demonstrating higher-order comorbid difficulties.

Like all learners, LM learners demonstrate a profile of unique strengths and weaknesses. LM learners generally develop word reading skills comparable to their non-LM peers in the early elementary grades but tend to demonstrate lower reading comprehension and language comprehension skills compared to their non-LM learner peers (Mancilla-Martinez & Lesaux, 2011; 2017). At the same time, LM learners may have relative advantages in other domain-general skills, particularly as they become proficient in English. For example, bilingual students tend to have an advantage in developing working memory as part of the executive function system, as they constantly navigate and switch codes between two languages (Bialystok, 2011). Further, research suggests a close connection between behavioral outcomes and LM learners' academic skills (Halle et al., 2012; Winsler et al., 2014). Winsler et al. (2014) found that LM students with greater initiative, self-control, and fewer behavioral problems achieved English proficiency more successfully than those with weaker skills in those domains.

Present Study

This study aimed to contribute to our understanding of predictors of higher-order comorbidity, focusing on LM learners, an historically underserved and growing student population. We addressed three interrelated research questions. First, what are the unique and shared risk factors of higher-order comorbid difficulties in reading comprehension and word-problem solving? Beyond the foundational academic skills (word reading and calculation), we investigate the risk factors in three categories: (a) behavioral attention, (b) cognitive processes (working memory, processing speed, and nonverbal reasoning), and (c) language (listening comprehension and vocabulary). Second, does the risk for higher-order comorbidity vary by LM status? Third, do the risk factors differ between at-risk LM learners compared to at-risk non-LM learners?

Method

Participants and Procedures

As part of a larger study on higher-order comorbidity, we screened second-grade students as at-risk (AR) or not-at-risk (NAR) for higher-order comorbid difficulties from 80 classrooms across 14 schools (11 Title 1; and 3 non-Title 1) where English was the language of classroom instruction. Among 1,318 consented students, we used the Single Digit Word-Problem Solving Test (SDWPS; Jordan & Hanich, 2000) and Gates MacGinitie Reading Test (GMRT; MacGinitie et al., 2000) with cut scores of 25^{th} percentile (using local norms for SDWPS and national norms for GMRT) to identify at-risk students and cut cores of 40^{th} percentile to identify not-at-risk students. We chose the 25th percentile because research has shown that students at this threshold are at-risk for developing pervasive difficulty in both those areas and it has been used to identify inadequate responders to intervention (Cho et al., 2015) and reading and math comorbid difficulties (Cirino et al., 2015).

This resulted in 409 students. An additional 92 students were not included in the study due to several reasons: students scoring below a T score of 37 on the Vocabulary and Matrix Reasoning subtest from the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999); moving out of the county; or having such limited English proficiency (as identified by the teachers) that they could not complete testing. LM status was identified based on school records. If a student received English learner services or had WIDA ACCESS scores or if the parents reported that a language other than English was used at home, the student was classified as a LM learner (see Table 1 for demographics).

These LM learners were heterogenous in their home language. Among LM learners whose parents reported home language (88%), Spanish was the home language of the majorities LM learners (65%), but parents reported more than 15 home languages. The total number of participants in the analytic sample was 317 (See Table 1 for the sample size information). In the fall of second grade, students were assessed in three individual testing sessions across 4–5 weeks by trained research assistants. All 16 testers were graduate-level students trained on each test by senior research staff, with mock testing sessions with peers as practice and then with the trainer. During training, a fidelity of testing checklist was completed. Each tester had to achieve 100% accuracy before working with students. Also, all testing sessions were audiotaped, and 15% were re-scored by an independent tester, with interrater agreement exceeding 99%.

Measures

All measures were administered in English. We assessed reading comprehension with Woodcock Johnson (WJ) IV Passage Comprehension (Schrank et al., 2014; split-half reliability = .93) where students are asked to read sentence(s) silently and supply a missing word in a cloze format. We assessed word-problem solving with the Applied Problem Solving subtest from the KeyMath-Revised (Connolly, 1998; split-half reliability =.67), which requires students to solve visually-presented word problems that are read out loud. The problems involve all four operations and solving multistep and nonroutine problems.

We used the following measures to assess potential risk factors. For calculation skill, we assessed accuracy with the Wide Range Achievement Test- 4th (WRAT4; Wilkinson & Robertson, 2006)-Arithmetic subtest (test-retest reliability .79), where students are asked to orally respond to questions related to number identification, counting, and number comparisons in Part I and have 10 minutes to complete calculation problems of increasing difficulties in Part II. For word reading, we assessed accuracy with WRAT4 (Wilkinson & Robertson, 2006; test-retest reliability .90), where students read words presented in isolation aloud until a ceiling is reached, and with the Vanderbilt Word Reading Test (Seethaler & Fuchs, 2017; α_{full} = .98; $\alpha_{at\text{-}risk}$ =.93), in which students are asked to read with two lists of words that sample grade-level sight words and intervention-aligned vocabulary words.

Behavioral attention was assessed with the inattention items (Items 1–9) from the Strengths and Weaknesses of ADHD-Symptoms and Normal-Behavior (Swanson et al., 2004; α_{full} =.98; $\alpha_{at\text{-}risk}$ = .96) scale. Teachers were asked to rate the student's attention problems compared to other students of the same age based on the observation over the past months. For cognitive processes, we assessed processing speed with the WJ IV Pair Cancelling (Schrank et al., 2014; test-retest reliability = .74), which asks students to cross out a certain visual stimulus when presented with rows of various randomly presented stimuli in 3 min. We measured working memory with the Working Memory Test Battery for Children (Pickering & Gathercole, 2001) Listening Recall and Counting Recall subtests (test-retest reliability for both subtests =.83). For the listening recall, the student is presented with a series of spoken sentences and asked to verify each sentence and then recalls the final word for each sentence in correct sequence. For the counting recall, the student is presented with a visual array of red circles and blue triangles and asked to count the number of circles in an array; then they recall the tallies of circles in the order in which they were presented. Nonverbal reasoning was assessed with the WASI Matrix Reasoning subtest (Wechsler, 1999; split-half reliability = .94), which indexes students' ability to complete the pattern.

We assessed vocabulary with the WASI vocabulary subtest (Wechsler, 1999; split-half reliability = .86), which requires orally presenting definitions of words presented visually and orally. We measured listening comprehension with the Woodcock Diagnostic Reading Battery (Woodcock, 1997; test-retest reliability = .80), which tests students' ability to understand sentences or brief paragraphs by asking students to supply a missing word.

Data Analyses

Preliminary analyses.—We did not find univariate nor multivariate outliers. Missing data was minimal (< 0.01 % missing) and was missing completely at random, $\chi^2(32) = 32.36$, $p = .45$. Prior to proceeding with primary analyses, we created sample-based z-scores and created composite scores for the constructs with more than one measures. We had a nested data structure in which students were nested within classrooms ($n = 68$) nested in schools ($n = 13$). The intra-class correlation at the classroom level ranged from .05 to .11 and .02 to .05 at the school level. Thus, we used maximum likelihood estimation with robust standard errors with TYPE = COMPLEX option in M*plus* to account for classroom-level clustering.

Primary analyses.—Initially, we fit the Lower-Order Academic Risk Model as a base model, where word reading and calculation accuracy predict reading comprehension and word-problem solving outcomes. Then a series of alternative path models were fit in the following steps to address the first research question. We included a set of risk factors as predictors of reading comprehension and word-problem solving directly and indirectly through word reading and calculation in the four subsequent models. The Behavioral Attention Risk Model included behavioral attention, the Language Risk Model included vocabulary and listening comprehension, and the Cognitive Risk Model included processing speed, working memory, and nonverbal reasoning. In the last model, the Multiple Deficits Model, all the risk factors were included. These mediation models test the hypothesized direct and indirect effects of domain-general risk factors on reading comprehension and word-problem solving via word reading and calculation. Given that these alternative models are non-nested, we compared the model fit using the sample size adjusted Bayesian Information Criteria (saBIC), selecting the model with lowest saBIC value as the best fitting model. In addition, we compared variance explained by each set of predictors, as well as the changes in residual correlation (Δr) compared to the Lower-order Academic Risk Model across the four competing models. For this last criterion, we expected the amount of residual correlation to drop substantially if the added set of risk factors was a primary source of comorbidity. If a set of risk factors fully explains the overlap between the two higher-order skills, the residual covariance would be close to zero.

To address the second research question, we examined whether LM learners were more likely to be identified as having risk for higher-order comorbidity compared to non-LM learners using a Chi-square test and calculated the odds ratio. The third research question was examined by running a series of ANOVA comparing LM vs. non-LM learners using only the AR sample. After conducting ANOVA, we applied the Benjamini-Hochberg (BH) correction to adjust *p*-values accounting for the family-wise error rate resulting from multiple comparisons within the same domain (Benjamini & Hochberg, 1995). We also calculated effect sizes as the standardized mean difference between each pair of groups using pooled standard deviation across both groups, correcting for small sample size (Hedges' *g*). M*plus* 8.3 (Muthén & Muthén, 1998–2019) was used for research question 1, and analyses for the second and third research questions were conducted using Stata IC 16.1 (StataCorp, 1985–2019).

Results

Correlations and Descriptive Statistics

Bivariate correlations suggest a substantial degree of overlap between reading comprehension and word-problem solving (see Table 2). Additionally, lower-order skills were highly correlated with higher-order skills in their respective domain, particularly for reading and less so for mathematics. Most of the risk factors were moderately correlated with reading comprehension and word-problem solving, except for processing speed. A summary of descriptive statistics is presented in the online supplemental material.

Research Question 1: Risk Factors of Higher-order Comorbidity

In the Lower-order Academic Risk Model, word reading was a significant predictor of reading comprehension ($\beta = .84$, $p < .01$) and calculation significantly predicted word-problem solving ($\beta = .50$, $p < .01$). Cross-over effects were observed, such that word reading predicted word-problem solving ($\beta = .31$, $p < .01$), and calculation predicted reading comprehension ($\beta = .09$, $p = .01$). Next, we added a set of predictor(s) in a series of four mediation models, where the risk factors were directly and indirectly related via word reading and calculation to higher-order skills.

Results of the saBIC, R^2, and residual correlation between reading comprehension and word-problem solving across the four competing models are presented in Table 3. The Multiple Deficits Model was the best fitting model based on all three indices. It had the lowest saBIC value, highest R^2 of reading comprehension and word-problem solving, and smallest residual correlation. In the Multiple Deficits Model (Table 4; Figure 1), only listening comprehension had a direct effect on reading comprehension. However, all the other risk factors, except processing speed, had indirect effects on reading comprehension via word reading. For word-problem solving, listening comprehension, behavioral attention, working memory, and vocabulary had direct effects. Moreover, all the risk factors, except listening comprehension, had indirect effects on word-problem solving via calculation. With the exception of processing speed, the total effects of each risk factor on both outcomes were significant.

Research Question 2: Risk Status by Language Group

The Chi-square test of equivalence indicated that LM learners are disproportionately identified as having risk for higher-order comorbid difficulties, $\chi^2(1) = 25.74$, $p < .01$. The odds of being identified with risk among LM learners was 2.02, but .61 for non-LM learners. This resulted in an odds ratio of 3.29. This suggests that the probability of being identified with risk versus not being identified with risk was more than three times higher for LM relative to non-LM learners.

Research Question 3: Differences in Risk Factors between LM vs. Non-LM Learners

Within the group of students with risk for higher-order comorbid difficulties, LM and non-LM learners had different risk factor profiles (unique strengths and weaknesses) (see Table 5). After applying the BH correction, LM learners performed lower on word reading accuracy ($g = -.35$) and reading comprehension ($g = -.40$); yet, no differences were found on mathematics-related measures ($-.12 \leq gs \leq .06$). LM learners also had relative weakness compared to non-LM learners in listening comprehension ($g = -.86$). However, the two groups did not differ on vocabulary ($g = -.15$) or on any of the cognitive processes ($.02 \leq gs \leq .17$). Finally, teachers rated LM learners as being more attentive than non-LM learners ($g = .42$). These statiscally significant differences remained significant after the BH correction.

Discussion

This study contributes to the growing research base on comorbidity by focusing on higher-order comorbidity of reading and mathematics difficulties, exploring higher-order comorbidity risk among LM and non-LM learners, and identifying profiles of LM and non-LM learners at risk for higher-order comorbidity. Three findings emerged. First, our findings indicate that higher-order comorbid difficulties are not attributed to deficits in a single factor. More uniquely, listening comprehension was the only shared risk factor explaining higher-order comorbidity. Second, compared to non-LM learners, LM learners were more likely to be identified as at risk for higher-order comorbidity. Third, compared to their at-risk non-LM learner peers, at-risk LM learners had lower levels of word reading, reading comprehension, and listening comprehension, but they had unique strengths in behavioral attention skills.

Unique and Shared Risk Factors of Higher-order Comorbidity

Our study findings align with the multiple deficits model (Pennington, 2006) by demonstrating that risk for higher-order comorbidity is multifactorial such that various domain-general risk factors are implicated in higher-order comorbid difficulties. This occurs either as having unique or shared pathways to reading comprehension and word-problem solving directly or indirectly through lower-order skills.

Although students with difficulties in reading comprehension and word-problem solving appear to share listening comprehension difficulties, other domain-general risk factors, such as behavioral attention, working memory, non-verbal reasoning, and vocabulary, contribute to higher-order comorbidity through a shared, indirect pathway via word reading and calculations. Beyond the documented correlations among domain-general risk factors (Table 2; .24 - .66), we extend the correlated liability hypothesis by demonstrating that domain-specific lower-order skills are correlated (.31), even after accounting for the effects of domain-general risk factors. Thus, we conclude that difficulties with word reading are associated with increased risk for calculation difficulties, or vice versa, which in turn heightens the risk for higher-order comorbid difficulties.

Unique Risk Factors—In terms of reading comprehension, word reading had a unique, direct pathway. What is most noteworthy is that word reading accounted for most of the variance in reading comprehension, leaving little variance for other predictors, such as listening comprehension, to explain. Students' reading comprehension skills are limited by their word reading skills, and it is difficult to differentiate the two skills from one another during the early years of reading development when many students are still at the stage of learning to read words (e.g., Mancilla-Martinez et al, 2019; Schankweiler et al., 1999). Indeed, we used a cloze format, sentence-level comprehension measure, which may rely more on word reading than listening comprehension in younger students (Keenan et al., 2008). Reading comprehension items designed for primary grade children like those in our study are necessarily less complex. Thus, vocabulary or domain-general cognitive processes critical for successful reading comprehension may not have emerged as shared risk factors of higher-order comorbidity considering the developmental reading stages and the characteristics of the reading comprehension measure for our second-grade sample.

In contrast to reading comprehension, there were several unique risk factors of word-problem solving, including calculation, behavioral attention, vocabulary, and working memory. Word reading was critical in word-problem solving in the Lower-Order Academic Risk Model, but it was no longer a significant predictor when all other risk factors were accounted for. Instead, other domain-general factors emerged as more important in predicting students' word-problem solving. As expected, the effect of processing on word-problem solving was indirect via calculation, suggesting that slow processing speed interferes with calculation performance, which creates a bottle neck for higher-order mathematics skills. Moreover, working memory served as a unique risk factor exerting both direct and indirect effects through calculation on word problem solving. These various unique direct and indirect influences of cognitive skills highlight that word-problem solving is a multi-step process that requires complex cognitive processes to be coordinated and maintained to successfully perform.

Shared Risk Factor—Given that teaching and learning most commonly unfold via verbal contexts, it is not surprising that listening comprehension emerged as a significant and shared reading comprehension and word-problem solving risk factor. But contrary to our expectation, when modeled with listening comprehension, vocabulary did not have a direct relation to reading comprehension and word-problem solving despite its moderately strong correlations (*r*s = .61 and .60, respectively). This finding may be related to differences in the breadth of language skills assessed by listening comprehension compared to vocabulary measures. Listening comprehension measures generally capture a wider range of language skills (e.g., syntactic awareness, vocabulary) to be coordinated at the sentence or passage levels, while vocabulary measures tend to tap language mainly at a lexical level. Thus, listening comprehension may represent a more comprehensive language proxy and, in turn, act as a more robust predictor of reading comprehension and word-problem solving. Another possible reason why listening comprehension emerged as a shared risk factor may be attributable to the format of word-problem solving measure because listening comprehension is heavily involved in KeyMath-R in elementary-aged students with language difficulties (Rhodes et al., 2015).

Higher-order Comorbidity and LM learners

As hypothesized from the pivotal role listening comprehension plays in comorbidity of higher-order skills, LM learners were approximately three times at higher risk for higher-order comorbidity than non-LM learners. Reading comprehension and word-problem solving heavily rely on language, particularly listening comprehension, and it can thus be expected that LM learners might struggle in both domains. Reading comprehension difficulties among LM learners are well-documented. Further, LM learners tend to be more heavily affected by the language demands of word problems compared to non-LM learners (Abedi & Lord, 2001). Indeed, identifying LM learners with higher-order comorbidity can be especially challenging as their struggles are likely confounded with their English language development. English is the primary language of instruction in the U.S., and the majority of assessments are administered only in English regardless of students' language status (Luk & Christodoulou, 2016). LM learners' low performance in any academic domain may be related to their English proficiency development and not to a specific learning disability (Santi et al., 2019).

We further explored this issue, via post-hoc analyses, by comparing LM learners who attained full English proficiency (non-English learners) and those officially classified with limited English proficiency (English learners) in the school system. The odds of being at risk for higher-order comorbidity for English learners were 23 times higher than non-English learners. This striking finding suggests the possibility of English language proficiency contributing to error in the identification process. It also raises questions about the appropriateness of inferences about LM learner's risk for learning disabilities when assessments are administered in English (Wolf et al., 2008). Although this was beyond the scope of this paper, this possibility warrants further investigation.

Reading and mathematics achievement gaps between LM and non-LM learners can vary depending on when LM learners attain English proficiency (e.g., Halle et al., 2012; Kieffer, 2008). Specifically, the earlier LM learners acquire English proficiency, the smaller the academic gap compared to their non-LM-learner peers. Further, the gap does not tend to exist if LM students enter school with full English proficiency. Of particular concern, studies have documented disproportionate representation of LM learners, particularly English learners, in special education as teachers tend to "wait and see" and delay special education referrals under the assumption that LM learners' low academic performance is attributable to delayed, yet normative, English development (e.g., Samson & Lesaux, 2009). Deferring identification is highly problematic, as social factors associated with LM learners in the U.S., such as limited English proficiency, should be evaluated separately and should not contribute to special education risk ratios. Missed early intervention opportunities for learning disabilities can compromise students' learning trajectories (e.g., Bruder, 2010), making LM learner identification and placement decisions essential for equitable educational outcomes. Practical and clinical challenges persist in untangling English development and learning disabilities among LM learners. While research on dynamic assessment has yet to directly address whether its capacity to differentiate mathematics learning disability from limited English proficiency in the LM population, dynamic assessment research points to its potential in identification and placement decisions for ELs (Petersen et al., 2018; Cho et al., 2020).

Profiles of At-Risk LM and Non-LM Learners

Within the group of students at-risk for higher-order comorbidity, LM learners had significantly lower word reading and reading comprehension skills compared to their non-LM learner peers. Prior studies suggest LM learners typically develop decoding and word reading skills comparably to that of English monolingual counterparts (e.g., August &

Shanahan, 2006; Mancilla-Martinez & Lesaux, 2011). However, newer findings point to compromised word reading skills among LM learners (e.g., Mancilla-Martinez et al., 2019). It may be that the second-grade LM learners in the present study, who were assessed in the beginning of the school year, had not yet received enough systematic, explicit word reading instruction to develop age-appropriate word reading skills. LM learners also evidenced lower reading comprehension than non-LM learners, which is unsurprising given their combined low word reading *and* listening comprehension profiles. Thus, instructional support in *both* basic word-level reading and comprehension skills is warranted for LM learners at risk for higher-order difficulties.

Of note, LM learners at risk for higher-order comorbidity also had unique strengths. Teachers' ratings of their behavioral attention were higher compared to ratings of non-LM learners, consistent with findings reported by Halle et al. (2012). Given the positive direct and indirect relationships of behavioral attention to higher order academic skills, the relative advantages in behavioral attention can be a leverage point for supporting LM learners' overall academic trajectories. Given the well-established role of behavioral attention to response to intervention (Al Otaiba & Fuchs, 2006), reinforcing LM learners' behavioral attention during instruction could bolster the effects of academic intervention.

Limitations and Future Directions

Our study findings should be interpreted with caution in light of several limitations. First, we used concurrent data, precluding causality claims between risk factors and reading and mathematics outcomes. Second, we did not include some domain-specific cognitive processes (e.g., rapid naming, number sense) used in prior studies to explain lower-order comorbidity risk factors, complicating comparisons with prior studies. Third, because our sample was not nationally representative, our odds ratio findings should be not be interpreted as a population-based prevalence rate. Fourth, none of the measures administered in English was normed specifically for LM learners, a long-standing and persistent issue in the field (e.g., Barrera, 2006; Klinger et al., 2006). Lower achievement of LM learners compared to non-LM learners may in part due to the English-only assessment, and we recommend future studies use bilingual assessment batteries to the extent possible. Despite these limitations, the strikingly large odds ratio underscores the need for future research on accurately identifying LM learners with risk for higher-order comorbidity. Our results highlight the important differences between at-risk LM and non-LM learners, with implications for tailoring interventions to the unique needs of LM learners.

Implication for Practice and Conclusion

Results of this study have the potential to advance understanding of underlying sources of higher-order comorbidity in students from diverse linguistic backgrounds. Further, findings can help inform the design of effective and efficient early intervention for LM and non-LM learners at risk for higher-order comorbidity. Listening comprehension emerged as a key shared factor for higher-order comorbidity. Also, LM learners at risk for higher-order comorbidities tended to have even lower scores on word reading and listening comprehension relative to non-LM learners at risk. Early interventions focused on promoting listening comprehension, word reading skills, and reading comprehension are warranted for students at risk for higher-order comorbidity.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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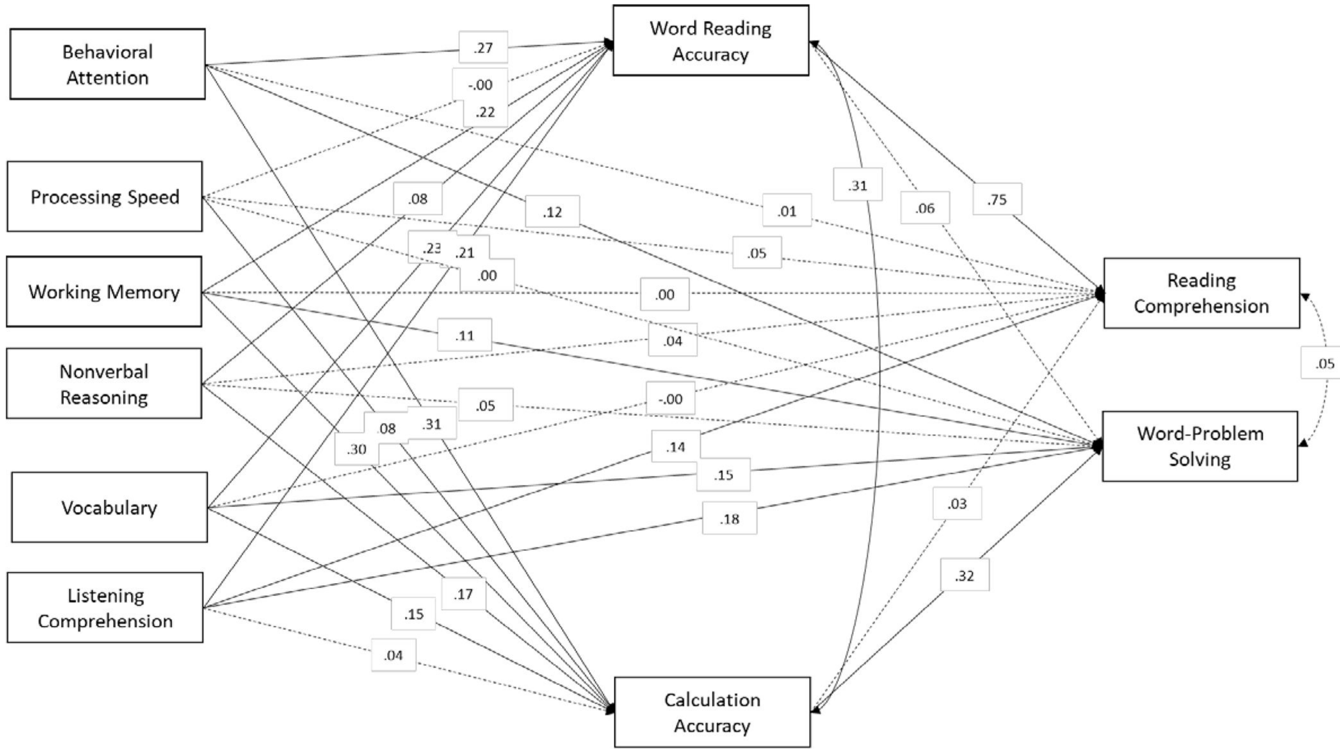

Figure 1.
Final Multiple Deficits Model

Note. This figure demonstrates the standardized path coefficients of the final Multiple Deficits Model. Solid lines indicate statistically significant paths at an alpha level of .05 and the dotted lines indicate statistically insignificant paths.

Table 1

Demographic Information by Risk and Language Status

	Non-LM		LM	
Variables	**At-risk (*n* = 70; 38%)**	**Not at-risk (*n* = 114; 62%)**	**At-risk (*n* = 89; 67%)**	**Not-at risk (*n* = 44; 33%)**
Gender				
Female	35	68	41	25
Male	35	45	47	19
Race				
African American	50	40	5	4
Asian	0	3	4	7
Hispanic	5	10	72	25
White	10	47	6	6
Other (including bi-racial)	5	12	2	2
Free/Reduced-priced Lunch				
No	14	73	40	22
Yes	56	36	46	21
Home Language Spoken				
Spanish	0	0	62	24
Other	0	0	14	18
Missing	70	114	13	2
EL Service				
No	70	113	13	35
Yes	0	0	76	9
IEP in Mathematics				
No	69	144	88	44
Yes	1	0	1	0
IEP in Reading				
No	68	144	88	44
Yes	2	0	1	0
Special education services				
No	59	109	82	44
Yes	11	3	7	0
			M (SD) *n* = 73	M (SD) *n* = 19
ACCESS Overall Proficiency Level			2.63 (.64)	4.18 (.58)

Note. Due to missing data, the cell counts do not add up to the total number of participants. LM = Language Minority; EL = English Learner; IEP = Individualized Education Program; ACCESS = WIDA ACCESS for ELs assessment. LM learners without the ACCESS scores were identified based on parent report of home language other than English and school records indicating the student receives English Language Service

Table 2

Correlations Among Academic and Risk Factor Variables

	Variables	1	2	3	4	5	6	7	8	9	10
Reading											
1	Word reading[a]										
2	Reading comprehension	.90									
Mathematics											
3	Calculation[a]	.71	.69								
4	Word-problem solving	.66	.66	.72							
Risk Factors											
5	Behavioral attention	.60	.57	.62	.57						
6	Working Memory[a]	.63	.62	.66	.62	.50					
7	Processing Speed	.29	.33	.36	.31	.29	.32				
8	Nonverbal Reasoning	.45	.47	.50	.46	.33	.45	.26			
9	Vocabulary	.63	.61	.54	.60	.40	.52	.24	.39		
10	Listening Comprehension	.66	.69	.56	.64	.48	.59	.31	.43	.66	

Note. All correlations were significant at an alpha level of .05.

[a]We created composite scores for constructs (working memory, word reading accuracy, calculation accuracy) with more than one measure using the average of sample-based z-scores.

Table 3

Alternative Model Comparisons

Alternative Models	Number of Parameter Estimated	saBIC	Residual correlation	Residual correlation *p*	R^2 RC	R^2 WPS
Behavioral Attention Risk Model	18	4038.912	.13	.03	.57	.82
Cognitive Risk Model	26	3959.88	.11	.09	.58	.83
Language Risk Model	22	3944.358	.06	.42	.61	.83
Multiple Deficits Model	38	3786.803	.05	.50	.63	.84

Note. saBIC = sample-size adjusted Baysian Information Criteria; RC = Reading Comprehension; WPS = Word-Problem Solving

Table 4

Path Analyses Results of the Multiple Deficits Models Explaining Unique and Shared Risk Factors of Higher-order Comorbidity (N = 317)

	Reading Comprehension								Word-Problem Solving							
			Indirect Effects via								Indirect Effects via					
	Direct Effects		Word Reading		Calculation		Total Effects		Direct Effects		Word Reading		Calculation		Total Effects	
Models	***beta***	***p***	***Beta***	***p***	***beta***	***p***	***beta***	***p***	***beta***	***p***	***beta***	***p***	***beta***	***p***	***beta***	***p***
Behavioral Attention Risk Model																
Word Reading[a]	.83	<.01							.26	<.01						
Calculation[a]	.08	.05							.44	<.01						
Behavioral Attention	.03	.48	.50	<.01	.05	.05	.57	<.01	.14	<.01	.16	<.01	.27	<.01	.57	<.01
Cognitive Risk Model																
Word Reading[a]	.81	<.01							.23	<.01						
Calculation[a]	.03	.38							.38	<.01						
Processing Speed	.06	.02	.06	.02	.01	.38	.12	<.01	.03	.55	.02	.03	.05	<.01	.10	.04
Working Memory[a]	.04	.30	.42	<.01	.02	.38	.48	<.01	.18	.00	.12	<.01	.19	<.01	.49	<.01
Nonverbal Reasoning	.06	.02	.16	<.01	.01	.38	.23	<.01	.08	.06	.05	<.01	.09	<.01	.22	<.01
Language Risk Model																
Word Reading[a]	.76	<.01							.12	.02						
Calculation[a]	.06	.10							.43	<.01						
Vocabulary	−.00	.97	.26	<.01	.02	.11	.27	<.01	.15	<.01	.04	.02	.13	<.01	.32	<.01
Listening Comprehension	.16	<.01	.33	<.01	.02	.11	.51	<.01	.22	<.01	.05	.03	.15	<.01	.43	<.01
Multiple Deficit Model																
Word Reading[a]	.75	<.01							.06	.22						
Calculation[a]	.03	.53							.32	<.01						
Behavioral Attention	.01	.77	.20	<.01	.01	.53	.22	<.01	.12	<.01	.02	.22	.10	<.01	.12	<.01
Processing Speed	.05	.08	−.00	.95	.00	.54	.05	.26	.00	.95	.00	.95	.03	.03	.03	.50
Working Memory[a]	.00	.97	.16	<.01	.01	.54	.17	<.01	.11	.02	.01	.26	.10	<.01	.22	<.01
Nonverbal Reasoning	.04	.07	.06	.02	.00	.54	.11	<.01	.05	.18	.01	.31	.06	<.01	.11	.01

Models	Reading Comprehension								Word-Problem Solving							
			Indirect Effects via								Indirect Effects via					
	Direct Effects		Word Reading		Calculation		Total Effects		Direct Effects		Word Reading		Calculation		Total Effects	
	beta	***p***	***Beta***	***p***	***beta***	***p***	***beta***	***p***	***beta***	***p***	***beta***	***p***	***beta***	***p***	***beta***	***p***
Vocabulary	−.00	.94	.18	<.01	.00	.54	.18	<.01	.15	<.01	.01	.21	.05	<.01	.21	<.01
Listening Comprehension	.14	<.01	.16	<.01	.00	.64	.30	<.01	.18	.01	.01	.25	.01	.51	.20	<.01

Note.

[a]We created composite scores for constructs (working memory, word reading, calculation) with more than one measure using the average of sample-based z-scores.

Table 5

Differences between LM and non-LM on Academic and Risk Factor Variables

	non-LM (*n* = 70)		LM (*n* = 89)				
Variables	***M***	***SD***	***M***	***SD***	***F***	***p***	***g***
Reading							
Word reading accuracy	−0.63	0.82	−0.90	0.74	4.76	.03	−0.35
Reading comprehension	−0.60	0.81	−0.89	0.65	6.28	.01	−0.40
Mathematics							
Calculation accuracy	−0.70	0.80	−0.74	0.76	0.14	.71	−0.06
Word-problem solving	−0.67	0.61	−0.74	0.56	0.57	.45	−0.12
Risk Factors							
Behavioral attention	−0.78	0.85	−0.47	0.67	6.84	.01	0.42
Working Memory	−0.65	0.82	−0.63	0.81	0.02	.88	0.02
Processing Speed	−0.38	1.01	−0.26	0.87	0.63	.43	0.13
Nonverbal Reasoning	−0.59	0.85	−0.46	0.70	1.10	.30	0.17
Vocabulary	−0.58	0.72	−0.70	0.83	0.88	.35	−0.15
Listening Comprehension	−0.30	0.65	−0.95	0.83	29.40	.00	−0.86

Note. LM = language minority learners; We created composite scores for constructs (working memory, word reading, calculation) with more than one measure using the average of sample-based z-scores.