Overview of the Vanderbilt LD Hub

Despite important advances in learning disabilities (LD) intervention, the dominant intervention approach—direct skills instruction—fails to meet the needs of many students. Therefore, innovative approaches are needed to target the specific needs of subgroups of students with LD (i.e., LD subtypes) to expand the framework for LD intervention.

This Project addresses a subset of the LD population that has been understudied. This population experiences disproportionately poor response to intervention and has a distinctive set of needs. These students have difficulty in math problem solving and reading comprehension.

With this understudied population, a transdisciplinary team of researchers investigates an innovative approach to LD intervention on math problem solving. This approach involves embedding tutoring on language comprehension in the same academic material that is used for direct skills math problem-solving intervention and the same academic material that is used for direct skills reading comprehension intervention, with scaffolding that occurs in parallel ways across domains. The key question is whether transfer occurs across domains on experimental tasks.

This LD Hub has the potential impact science by increasing understanding about this LD subtype (with combined reading comprehension and math problem-solving difficulty) as an LD subtyping framework and about the role of language comprehension in math problem-solving, reading comprehension, and comorbidity. The Project has the potential to impact clinical practice by testing the viability of this LD subtype as a framework to differentiate instruction, via a novel intervention, and thereby meet the needs of a greater proportion of students with LD.

What This Link Provides

This link provides information on the Vanderbilt LD Hub’s research papers, as well as other Vanderbilt papers related to the topic of the LD Hub. This link also provides information about procedures for database usage.
Requesting Papers
See below for citations, with abstracts, to the Vanderbilt LD Hub’s publications and other relevant Vanderbilt investigator or scholar studies. To request an email copy of a paper, Contact amber.y.wang@vanderbilt.edu with the reference of the requested paper.

In this paper, we consider evidence from our intervention research programs on whether students with concurrent difficulty in reading and mathematics respond differentially to intervention and therefore represent distinct forms of learning disability (LD) requiring distinctive forms of intervention. We begin by examining academic and cognitive profiles of reading LD versus mathematics LD versus comorbid LD, thereby generating hypotheses about differential instructional needs of students with comorbid reading and mathematics LD. Then, to gain insight into the tenability of these hypotheses, we report analyses conducted on extant databases to consider whether and if so how students with LD in comorbid versus one area of disability respond differentially to word-problem intervention, to math facts intervention, and to most intensive forms of reading intervention. We conclude with recommendations for future research to promote valid identification of comorbid LD samples and to extend understanding of LD subtyping frameworks for improving the field’s success in helping students with LD achieve greater academic success.

This study’s hypotheses were that (a) WP solving is a form of text comprehension that involves language comprehension processes, working memory, and reasoning, but (b) WP solving differs from other forms of text comprehension by requiring WP-specific language comprehension as well as general language comprehension. At start of 2nd grade, children (n=206; on average, 7 years 6 months) were assessed on general language comprehension, working memory, non-linguistic reasoning, processing speed (a control variable), and foundational skill (arithmetic for WPs; word reading for text comprehension). In spring, they were assessed on WP-specific language comprehension, WPs, and text comprehension. Path analytic mediation analysis indicated that effects of general language comprehension on text comprehension were entirely direct, whereas effects of general language comprehension on WPs were partially mediated by WP-specific language. By contrast, effects of working memory and reasoning operated in parallel ways for both outcomes.

The purpose of this study was to examine the cognitive predictors of calculations and number line estimation with whole numbers and fractions. At-risk 4th-grade students (N = 139) were assessed on 7 domain-general abilities (i.e., working memory, processing speed, concept formation, language, attentive behavior, and nonverbal reasoning) and incoming calculation skill at the start of 4th grade. Then, they were assessed on whole-number and fraction calculation and number line estimation measures at the end of 4th grade. Structural equation modeling and path analysis indicated that processing speed, attentive behavior, and incoming calculation skill were significant predictors of whole-
number calculations whereas language, in addition to processing speed and attentive behavior, significantly predicted fraction calculations. In terms of number line estimation, nonverbal reasoning significantly predicted both whole-number and fraction outcome, with numerical working memory predicting whole-number number line estimation and language predicting fraction number line estimation. Findings are discussed in terms of distinctions between whole-number and fraction development and between calculations and number line learning.


The purpose of this study was to identify cognitive and linguistic predictors of word problems with versus without irrelevant information. The sample was 701 2nd-grade students who received no specialized intervention on word problems. In the fall, they were assessed on initial arithmetic and word-problem skill as well as language ability, working memory capacity, and processing speed; in the spring, they were tested on a word-problem measure that included items with versus without irrelevant information. Significant predictors common to both forms of word problems were initial arithmetic and word problem-solving skill as well as language and working memory. Nonverbal reasoning predicted word problems with irrelevant information, but not word problems without irrelevant information. Findings are discussed in terms of implications for intervention and research.


Children (n=747; 6.5 years) were assessed on domain-general processes and mathematics and reading-related competencies (start of 1st grade); addition retrieval (end of 2nd grade); and calculations and word reading (end of 3rd grade). Attentive behavior, reasoning, visuospatial memory, and rapid automatized naming (RAN) indirectly contributed to both outcomes, via retrieval. However, there was no overlap in domain-general direct effects on calculations (attentive behavior, reasoning, working memory) versus word reading (language, phonological memory, RAN). Results suggest ease of forming associative relations and abilities engaged during the formation of these long-term memories are common to both outcomes and can be indexed by addition fact retrieval, but further growth in calculations and word reading is driven by different constellations of domain-general abilities.


The purpose of this study was to examine child-level pathways in development of pre-algebraic knowledge versus word-problem solving, while evaluating the contribution of calculation accuracy and fluency as mediators of foundational skills/processes. Children (n = 962; mean 7.60 years) were assessed on general cognitive processes and early calculation, word-problem, and number knowledge at start of grade 2; calculation accuracy and calculation fluency at end of grade 2; and pre-algebraic knowledge and word-problem solving at end of grade 4. Important similarities in pathways were identified, but path analysis also indicated that language comprehension is more critical.
for later word-problem solving than pre-algebraic knowledge. We conclude that pathways in development of these forms of 4th-grade mathematics performance are more alike than different, but demonstrate the need to fine-tune instruction for strands of the mathematics curriculum in ways that address individual students’ foundational mathematics skills or cognitive processes.


The purpose of this study was to assess the added value of dynamic assessment (DA) for predicting individual differences in year-end first-grade calculation (CA) and word-problem (WP) performance as a function of limited English proficiency (LEP) status. Beginning first graders (129 LEP; 163 non-LEP) were assessed on brief, static math tests, static tests of domain-general abilities (vocabulary; reasoning), and DA. The next spring, they were assessed on CA and WP. Regression analyses indicated that the value of the predictor depends on the predicted outcome and LEP status. In predicting CAs, the extended math test and DA uniquely explained variance for LEP children, with strong predictive value for the extended math test; for non-LEP children the extended math test was the only significant predictor. However, in predicting WPs, only DA and vocabulary were uniquely predictive for LEP children, with stronger value for DA; for non-LEP children, the extended math test and DA were comparably uniquely predictive. The potential value of a gated screening process is discussed.


The relation between 2 forms of mathematical cognition, calculations and word problems, was examined. Across grades 2-3, performance of 328 children (mean starting age 7.63 [SD=0.43]) was assessed 3 times. Comparison of a priori latent change score models indicated a dual change model, with consistently positive but slowing growth, described development in each domain better than a constant or proportional change model. The bivariate model including change models for both calculations and word problems indicated prior calculation performance and change were not predictors of subsequent word-problem change, and prior word-problem performance and change were not predictors of subsequent calculation change. Results were comparable for boys versus girls. The bivariate model, along with correlations among intercepts and slopes, suggest calculation and word-problem development are related, but through an external set of overlapping factors. Exploratory supplemental analyses corroborate findings and provide direction for future study.


Using multitrait, multimethod data, & confirmatory factor analysis, we examined effects of arithmetic item formatting and the possibility that across formats, abilities other than arithmetic may contribute to performance. Hypotheses were guided by 4 competing frameworks, using 11 measures of arithmetic with symbolic format and various problem demands. As predicted by Triple Code Theory, arithmetic outcomes with language formatting, Arabic numeral formatting, and estimation demands were related but distinct
from one another. As predicted by Encoding Complex Theory, executive attention was a direct predictor of all arithmetic outcomes. Language was no longer a direct predictor of arithmetic outcomes when executive attention was accounted for in the model, but a strong and enduring relation between language and executive attention suggested language may play a facilitative role in reasoning during numeric processing. Findings suggest that beyond arithmetic-focused interventions, interventions targeting executive attention, language, or the interplay between them may be promising avenues of math problem-solving intervention.


We identified child-level predictors of responsiveness to 2 types of mathematics (calculation and word-problem) intervention among 2nd-grade children with mathematics difficulty. Participants were 250 children in 107 classrooms in 23 schools pretested on mathematics and general cognitive measures and posttested on mathematics measures. We assigned classrooms randomly assigned to calculation intervention, word-problem intervention, or business-as-usual control. Intervention lasted 17 weeks. Path analyses indicated that scores on working memory and language comprehension assessments moderated responsiveness to calculation intervention. No moderators were identified for responsiveness to word-problem intervention. Across both intervention groups and the control group, attentive behavior predicted both outcomes. Initial calculation skill predicted the calculation outcome, and initial language comprehension predicted word-problem outcomes. These results indicate that screening for calculation intervention should include a focus on working memory, language comprehension, attentive behavior, and calculations. Screening for word-problem intervention should focus on attentive behavior and word problems.


The 3 purposes of this study were to (a) describe fraction ordering errors among at-risk fourth grade students, (b) assess the effect of part-whole understanding and accuracy of fraction magnitude estimation on the probability of committing errors, and (c) examine the effect of students’ ability to explain comparing problems on the probability of committing errors. Students (N = 227) completed a nine-item ordering test. A high proportion (81%) of problems were completed incorrectly. Most (65%) errors were due to students misapplying whole number logic to fractions. Fraction-magnitude estimation skill, but not part-whole understanding, significantly predicted the probability of committing this type of error. Implications for practice are discussed.


The purpose of the study was to determine whether individual differences in at-risk 4th graders’ language comprehension, nonverbal reasoning, concept formation, working memory, and use of decimal labels (i.e., place value, point, incorrect place value, incorrect fraction, or whole number) are related to their decimal magnitude understanding. Students (n = 127) completed 6 cognitive assessments, a decimal labeling assessment, and 3 measures of decimal magnitude understanding (i.e., comparing decimals to the fraction benchmark task, estimating where decimals belong
on a 0-1 number line, and identifying fraction and decimal equivalencies). Each of the domain-general cognitive abilities predicted students’ decimal magnitude understanding. Using place value labels was positively correlated with students’ decimal magnitude understanding, whereas using whole-number labels was negatively correlated with students’ decimal magnitude understanding. Language comprehension, nonverbal reasoning, and concept formation were positively correlated with students’ use of place value labels. By contrast, language comprehension and nonverbal reasoning were negatively correlated with students’ use of whole number labels. Implications for the development of decimal magnitude understanding and design of effective instruction for at-risk students are discussed.


The goal of the present study was to describe fraction-calculation errors among 4th-grade students and determine whether error patterns differed as a function of problem type (addition vs. subtraction; like vs. unlike denominators), orientation (horizontal vs. vertical), or mathematics-achievement status (low- vs. average- vs. high-achieving). We specifically addressed whether mathematics-achievement status was related to students’ tendency to operate with whole number bias. We extended this focus by comparing low-performing students’ errors in two instructional settings that focused on two different types of fraction understandings: core instruction that focused on part-whole understanding vs. small-group tutoring that focused on magnitude understanding. Results showed students across the sample were more likely to operate with whole number bias on problems with unlike denominators. Students with low or average achievement (who only participated in core instruction) were more likely to operate with whole number bias than students with low achievement who participated in small-group tutoring. We suggest instruction should emphasize magnitude understanding to sufficiently increase fraction understanding for all students in the upper elementary grades.


This study examined differences in cognitive processing between 4th-grade students who respond adequately versus inadequately to intervention on 3 fraction outcomes: number-line estimation, calculation, and word problems. Students were assessed on 7 cognitive processes and the 3 fraction outcomes. Students were grouped as adequate or inadequate responders using as the cut-point the control-group mean on pre-to-post improvement on the relevant measure. Between-group differences identified reasoning, concept formation, and listening comprehension related to all 3 fraction outcomes. On the number-line outcome, within-group profile analysis indicated inadequate responders experienced low reasoning ability relative to their other forms of cognitive processing.


This purpose of this analysis was to provide insight on whether word-problem (WP) solving is a form of text comprehension (TC) and on the role of language comprehension in WPs. A sample of 325 2nd graders, representing high, average, and low reading and
math performance, was assessed on (a) start-of-year TC, language comprehension (LC), non-linguistic reasoning, working memory, and foundational skill (word identification, arithmetic) and (b) year-end WP-solving, WP-language processing (understanding WP statements, without calculation demands), and calculations. Multivariate, multilevel path analysis, accounting for classroom and school effects, indicated TC was a significant and comparably strong predictor of all outcomes. Start-of-year LC was a significantly stronger predictor of both year-end WP outcomes than of calculations, whereas start-of-year arithmetic was a significantly stronger predictor of calculations than of either WP measure. Implications are discussed in terms of WP solving as a form of TC and a theoretically coordinated approach, focused on LC, for addressing TC and WP-solving instruction.


The purposes of this study were to (a) explore whether early fractions understanding at 4th grade is differentially challenging for students with versus without adequate whole-number competence and (b) identify specific whole-number skill associated with difficulty in fractions understanding. Based on initial whole-number competence, 1,108 4th graders were classified as having (a) adequate whole-number competence \((n = 775)\), (b) less severe whole-number difficulty \((n = 201)\), and (c) severe whole-number difficulty \((n = 132)\). At the end of 4th grade, they were assessed on fractions understanding and further classified as with versus without difficulty in fractions understanding. Multi-level logistic regression indicated that compared to students with adequate whole-number competence, those with less severe whole-number difficulty were almost 5 times as likely to experience difficulty with fractions understanding whereas those with severe whole-number difficulty were about 32 times as likely to experience difficulty with fractions understanding. Among students with adequate whole-number competence, the pretest whole-number skills distinguishing those with versus without difficulty in fractions understanding was basic division facts (i.e., 2-digit dividend ÷ 1-digit divisor) and simple multiplication (i.e., 3-digit × 1-digit without regrouping).


Disorders of reading, math, and attention frequently co-occur in children. However, it is not yet clear which cognitive factors contribute to comorbidities among multiple disorders and which uniquely relate to one, especially because they have rarely been studied as a triad. The present study considers how reading, math, and attention relate to phonological awareness, numerosity, working memory, and processing speed, all implicated as unique or shared correlates of these disorders. In response to findings that the attributes of all 3 disorders exist on a continuum rather than representing qualitatively different groups, this study employed a dimensional approach. Further, we used both timed and untimed academic variables in addition to attention and activity level variables. Results support the role of working memory and phonological awareness in the overlap among reading, math, and attention, with a limited role of processing speed. Numerosity was related to comorbidity between math and attention. Results from timed variables and activity level were similar to those from untimed and attention variables, although activity level was less strongly related to cognitive and academic/attention variables. Findings have implications for understanding cognitive
deficits that contribute to comorbid reading disability, math disability, or attention deficit/hyperactivity disorder.


Algebraic competence is a major determinant of college access and career prospects, and equal sign knowledge is taken to be foundational to algebra knowledge. However, few studies have documented a causal effect of early equal sign knowledge on later algebra skill. This study assessed whether 2nd-grade students’ equal sign knowledge prospectively predicts their 4th-grade algebra knowledge, when controlling for demographic and individual difference factors. Children (*n* = 177; *M* = 7.61) were assessed on a battery of tests in grade 2 and on algebraic knowledge in grade 4. Second-grade equal sign knowledge was a powerful predictor of these algebraic skills. Findings are discussed in terms of the importance of foregrounding equal sign knowledge to promote effective pedagogy and educational equity.


In this article, we describe 2 practices that have emerged from high-quality research studies as particularly effective for word-problem instruction are: (a) attack strategies, which provide students with a general plan for processing and solving word problems, and (b) schema instruction, in which students learn to categorize word problems within problem types; apply an efficient solution strategy for each word-problem schema; and understand the meaning of word-problem language.


The purpose of this study was to explore interactions between limited English proficiency (LEP) status, as a function of risk status (low math performance at the start of the school year), on computation and word-problem solving performance. Among 260 1st-grade students, classified as at-risk (AR) or not at-risk (NAR) for math disability, we compared the performance of LEP students to native English-speaking peers. A series of 2-way ANOVAs were conducted on computation and word-problem solving skill at 2 time points, fall and spring of 1st-grade. On fall computation measures, there was no main effect for LEP status and no interaction between LEP and risk status. On spring computation, a main effect for LEP status had emerged, but again no interaction. By contrast, on fall word-problem solving, there was an interaction between LEP and risk status; however, this interaction was no longer significant by spring. Results suggest that language proficiency is an important factor in the development of computation and word-problem solving skill. Implications for future research are discussed.


This study explored the developmental trajectories and predictors of word reading and reading comprehension among young at-risk readers. In fall of 1st grade, 185 students identified as at-risk for reading difficulties were assessed on measures of domain-specific skills (phonological awareness, letter knowledge, vocabulary), domain-general skills (working memory, non-verbal reasoning, processing speed), and word reading and reading comprehension. Word reading and reading comprehension were assessed
again in spring of grades 1-4. Individual growth curve modeling showed that children demonstrated decelerated growth on word reading and linear growth on reading comprehension, although their performance on both word reading and reading comprehension were consistently below average on national norms. After controlling for word reading and reading comprehension in 1st grade, letter knowledge predicted growth in word reading; vocabulary and non-verbal reasoning predicted growth in reading comprehension. Thus, developmental trajectories and predictors differed for word reading and reading comprehension among our at-risk sample. Implications are discussed for theory and early reading instruction for at-risk children.


This study investigates the relationship among home language use practices, Spanish-speaking parents’ beliefs about dual language development, and their elementary-aged children’s vocabulary knowledge. Parents ($n = 162$) completed a questionnaire about their home language use practices and beliefs about dual language development, and children ($n = 190$) completed vocabulary assessments. Principal component analyses revealed that Spanish-speaking parents’ beliefs about dual language development are heterogeneous, and that these beliefs can be characterized differently according to their children’s English proficiency designations and grade levels. Structural equation modeling analyses revealed that the Bilingual Facility parent belief factor was associated with home language use practices, which, in turn, were associated with children’s vocabulary scores. However, this association only applied to limited English proficient and Kindergarten students and their parents. These results underscore the importance of attending to parental beliefs, as they appear to relate to home language use practices and children’s vocabulary achievement.


Neurobiological studies of naturalistic language comprehension have almost exclusively focused on narrative comprehension. However, successful engagement in modern society, particularly in educational settings, equally requires comprehension with an aim to learn new information (“expository comprehension”). Despite its prevalence, no studies to date have neurobiologically characterized expository comprehension as compared to narrative. We used functional magnetic resonance imaging (fMRI) in typically developing children to test whether different genres require specialized brain networks. We found that, compared to narrative comprehension, expository comprehension uniquely recruited a top-down, goal-oriented network (the frontoparietal control network; FPN) and relied significantly less on areas supportive of social cognition (the default mode network; DMN). Also, in expository comprehension the FPN showed robust interactions with the DMN, and this inter-network communication was higher with increased reading expertise. Our findings reveal that different types of naturalistic language comprehension place diverse neural demands on young readers.


We investigated the predictive longitudinal relations between cognitive skills, specifically language-related skills, and word-problem solving in 340 children (6.10 to 9.02 years). We used structural equation modeling to examine whether word-problem solving,
computation skill, working memory, nonverbal reasoning, oral language, and word reading fluency measured at 2nd grade forecasted performance on measures of word-problem solving in 4th grade. Results indicated that prior word-problem solving, computation skill, nonverbal reasoning, and oral language were significant predictors of children’s later word-problem solving. Multi-group modeling suggested that these relations were not differentially predictive for boys versus girls. Implications of these findings are discussed.


In this article, we discuss the approach adopted within the Vanderbilt University Learning Disabilities Innovation Hub, which focuses on students with higher-order comorbidity: students with concurrent difficulty with reading comprehension and word-problem solving. The aim of the Hub’s Research Project, is to test what we refer to as the higher-order comorbidity hypothesis: that language comprehension plays a critical role in reading comprehension and word-problem solving. We specifically hypothesize that language comprehension offers a coordinated approach for improving both outcomes and that this approach can thus provide direction for understanding higher-order comorbidity. The hope is that the Hub’s experimental manipulation will offer support for the validity of reading comprehension and word-problem solving comorbidity as a learning disabilities subtyping framework. In the first segment of this article, we describe a theoretical model that connects reading comprehension and word-problem solving development via oral language comprehension, and we provide a brief overview of prior related research on these connections. This first section provides the basis for the second segment of this article, in which we discuss the Vanderbilt Hub’s innovative approach for investigating these connections using an experimental manipulation. This causal study tests a theoretically-coordinated framework for synergistically improving performance in both high-priority domains of academic development, while exploring effects for boys versus girls and for linguistically diverse learners.

Requesting Information on Database Usage
The Project study, which is in progress, will include data from 455 second-grade children identified with comorbid LDs or as average or high in MPS & RC. The final data set will comprise parent or teacher reported information, teacher reports of attentive behavior, and experimental mathematics and reading tasks, and linguistic/cognitive abilities. Variables will become available as manuscripts reporting on those variables are published. The Core will prepare and make de-identified datasets electronically available to external users under a data-sharing agreement that provides for (1) a commitment to using the data only for the research purposes described in the user’s request; (2) assurance that no individual will be identified for any purpose; (3) a commitment to secure the data using appropriate computer technology; (4) a commitment to destroying or returning the data after analyses are completed; and (5) guarantees that publications are credited to NICHD and to this grant and are entered into PubMed. The outside user will submit a request to L. Fuchs describing variables of interest, the research purpose/questions, the quantitative methods to be applied to the requested data, and how those methods will answer the research questions. Within 2 months of the outside user’s request, L. Fuchs in collaboration with the other Hub Investigators will formulate a decision, based on whether the proposed variables are part of the database; the research questions can be answered with those variables; and the plan is internally consistent, quantitatively sound, and tenable. If so, the decision is yes, and a
database with the variables of interest will be provided, along with the code book for those variables. If not, we will provide a written communication explaining this decision. If we are unclear, we will provide a written request for clarifications, with up to 2 rounds. If approved, L. Fuchs will prepare and send a Data Use Agreement Form to the outside user (outlining terms for data use & guarantees). The relevant (de-identified) data will then be extracted and provided to the user along with relevant portions of the code book. We will also provide a published study that describes the sample, study, and procedures. For additional information, contact lynn.fuchs@vanderbilt.edu.