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Empirical study

Validation of the direct and inferential mediation (DIME) model of reading comprehension in grades 7 through 12

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ABSTRACT

This study evaluated the direct and inferential mediation (DIME) model of reading comprehension (Cromley & Azevedo, 2007) in a large ($n = 1196$) and diverse (grades 7–12) sample. Multi-indicator latent variables were used to measure six primary constructs: knowledge, vocabulary, word reading, strategies, inference, and reading comprehension. Results corroborated prior research when similar methods were used, but departed from prior findings when measurement error and shared method variance between the predictors and the reading comprehension outcomes (method bias) were controlled. Results generalized across middle and high school, and component skills of reading accounted for virtually all of the systematic variance in reading comprehension. Importantly, controlling method bias diminished the importance of knowledge and vocabulary, and increased the importance of inferencing. Mediated effects of knowledge and vocabulary through inference making were also found. The present study provided a stronger and more generalizable formulation of the DIME model than prior research, and highlighted limitations of using reading-based measures of predictors in component skills models of reading comprehension.

1. Introduction

National and international studies reveal that significant numbers of adolescents and young adults do not adequately understand complex texts, impeding their school success, access to post-secondary learning, and opportunities within our increasingly competitive work environment (Biancarosa & Snow, 2004; Kamil et al., 2008). Annual student growth in reading achievement is greatest during elementary school and declines over time, with high school students making the least growth (Bloom, Hill, Black, & Lipsey, 2008; Francis, Shaywitz, Stuebing, Shaywitz, & Fletcher, 1996). Reports by American College Testing (ACT, 2006, 2009) reveal that only 50% of the ACT-tested students who self-identified as being interested in post-secondary schooling were ready to read and understood college-level text. The 2006 report stated, "the clearest differentiator between students who are college ready and students who are not is the ability to understand complex text" (ACT, 2006, p. 16). Males, African Americans, Hispanic Americans, Native Americans, and students from families whose incomes were less than $30,000 were most at risk for having very low reading comprehension (ACT, 2006, 2009); 55% of students with low literacy levels did not graduate from high school (National Commission on Adult Literacy (NCAL), June 2008).

As is true for other academic domains (e.g., Vellutino, Fletcher, Snowling, & Scanlon, 2004), testable models of reading comprehension are important for understanding individual differences and for identifying appropriate targets for intervention. Because the relative contributions of component skills to reading comprehension change across age/grade (Tighe & Schatschneider, 2014; van den Broek et al., 2005; Verhoeven & Van Leeuwe, 2008), and may also vary as a function of skill level, it is important that models of reading comprehension take these factors into account.

A well-established and robust model of the components underlying proficiency in reading comprehension is the Simple View of Reading (SVR; Hoover & Gough, 1990). The SVR parsimoniously holds that RC = D × LC (i.e., Reading Comprehension = Decoding × Listening Comprehension), which represents mathematically that decoding and listening comprehension are each necessary but not sufficient for text comprehension. Although the SVR is a parsimonious framework, it is based on the LaBerge and Samuels theory (1974), which is an interactive hypothesis that includes a broad range of phenomena that accounts for decoding, rather than an automatized conceptualization of word reading attributed to the Simple View.

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Nonetheless, the SVR does not specify causal relations among malleable component skills, and the most useful application of the SVR has been the evaluation of bottleneck variables (e.g., decoding). The SVR has been widely replicated using alternative measures of decoding (i.e., word and non-word reading accuracy and fluency; Florit & Cain, 2011), and language (i.e., vocabulary and listening comprehension; Tunmer & Chapman, 2012), and has been extensively studied in shallow and deep orthographies (Florit & Cain, 2011). Although additional components such as working memory, phonological awareness and rapid naming have been added to the SVR model, the most common variations are in the measures, sampling procedures, and analytic techniques (Florit & Cain, 2011; Tunmer & Chapman, 2012).

Another components-based model, the Direct and Inferential Mediational Model (DIME model) complements cognitive-processing theories of reading comprehension. The DIME model is subsumed within the SVR framework, where word reading represents the decoding component, and background knowledge and vocabulary represent the linguistic component. In addition, text-processing components (i.e., inference making and reading strategies) also represent the linguistic component of the SVR.

The DIME model aligns well with theoretical models of reading comprehension such as the Construction-Integration model (Kintsch, 1998), Structure-Building framework (Gernsbacher, Varner, & Faust, 1990), and Verbal-Efficiency theory (Perfetti, 1985), which provide a framework for understanding the dynamics underlying reading comprehension. The DIME model is an example of an empirical evaluation of theoretical frameworks that treat measureable components involved in reading comprehension as a set of interrelated processes, focusing on those components and their relations in a more static model of reading comprehension. Thus, how malleable processes[1] interact in theories of reading comprehension can be tested empirically with directional, moderated, and/or mediated relations among component skills.

The DIME model represents a valuable departure from the SVR framework in that it attempts to integrate components from text processing theories of comprehension. The DIME model relies on predictors of reading comprehension derived from a data-base of 98 research studies. According to the authors, a strength of the DIME model is that a path was hypothesized only when there was empirical evidence supporting it as evidenced by one or more experimental studies. Nonetheless, the DIME model has not been tested using (a) measures from the text-processing literature, (b) multiple measures per construct, and (c) with a large and diverse sample of middle and high school students. In the next sections, we discuss the development of the original DIME model, and the follow-up replication of the model, and then present the purpose of the current study. We start, however, by discussing the importance of accounting for measurement issues in models of reading comprehension.

1.1. Component skills are confounded by reading requirements

As illustrated by the SVR, word reading is strongly related to reading comprehension. Often overlooked in the research literature, component skills of comprehension are often confounded with reading, because researchers measure the component skills using assessments that are based on students interacting with text, thus requiring participants to read material when assessing the component skill. Thus, the measured relations between the component skills and reading comprehension are inflated by the shared methods used to assess both the component skills and reading comprehension (shared method variance or method bias). For example, research has identified vocabulary—or a person's mental lexicon—as an important determinant of reading comprehension. Because neither the depth nor the breadth of a person's mental lexicon is directly knowable, we assess this skill through measures of vocabulary. In doing so, researchers can choose among different measures of vocabulary. Some of these assessments require the individual to read a text and match a word to its definition presented in text; other measures do not require reading, such as picture vocabulary measures, or measures presented aurally. Thus, on an assessment of the first type, the ability to answer an item correctly may reflect both word knowledge *and* the ability to read and comprehend the item, whereas on an assessment of the latter type, the ability to answer an item correctly is not dependent on the individual's ability to read. This confounding of the component skill and reading comprehension through the reading of test stimuli threatens the validity of inferences about the magnitude of the relation between the two constructs. Under such circumstances, our estimates of the associations among the component skills and of the effect of the component skills on reading comprehension may be biased.[2] The problem for studies of reading comprehension is that the bias is introduced by unmeasured method variance that is related to, but is not the same as, word reading, and thus is not controlled simply by adding measures of word reading to the model. The unmeasured bias could be related to reading rate or reading fluency, test taking experience, experience with print, or other factors that are confounded with reading comprehension as well as the measurement of the component skills (Paris, Carpenter, Paris, & Hamilton, 2005).

1.2. The DIME model

In a path analysis involving 177 ninth grade students with a wide range of reading ability, Cromley and Azevedo (2007) reported that vocabulary and background knowledge had a direct influence on comprehension and influenced comprehension indirectly by mediating inference-making. Word reading directly enhanced comprehension. In addition, there were indirect effects of knowledge on comprehension through strategies, and of strategies on comprehension through inference. The largest effects on comprehension were for vocabulary and knowledge followed by inferencing, word reading and strategies. Word reading skills and inferencing accounted for comparable amounts of variance.

In a subsequent study, Cromley, Snyder-Hogan, and Luciw-Dubas (2010) modeled the same hypothesized components of comprehension in relation to science achievement in a larger sample of 737 students in an introductory college level biology course. Passages were written to reflect material taught in the biology course, leading to development of a comprehension measure and measures of strategy, inferencing, domain-specific knowledge, and vocabulary derived from the passages. Structural equation modeling (SEM) was used to evaluate the components (measurement model) and paths hypothesized by the DIME model. Because SEM is facilitated by multiple indicators of each hypothesized latent variable, item parcels from the same assessment were used to create three forms of each

[1] In education research, malleable processes refer to factors that can be experimentally manipulated and may be targets for intervention. In the case of reading comprehension, well known malleable processes include decoding, vocabulary, background knowledge, inference making, and strategy use.

[2] Common method variance (CMV) refers to variance that is attributable to measurement method rather than to the constructs the measures represent (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003; Podsakoff, MacKenzie, & Podsakoff, 2012). As such, CMV represents an unmeasured source of covariation among measures, which is spurious, i.e., not due to correlations between the constructs of interest. Other examples of CMV include test characteristics (e.g., response formats such as multiple choice vs. Likert scale) and item characteristics (e.g., positively vs. negatively worded items, or similarly worded items).