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Hierarchical and Dynamic Relations of Language and Cognitive Skills to Reading Comprehension: Testing the Direct and Indirect Effects Model of Reading (DIER)

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We investigated 2 hypotheses of a recently proposed integrative theoretical model of reading, the direct and indirect effects model of reading (DIER; Kim, 2017b, 2019): (a) hierarchical relations and (b) dynamic relations (or differential relations) of skills to reading comprehension. Students were assessed on reading comprehension, word reading, listening comprehension, working memory, attention, vocabulary, grammatical knowledge, perspective taking (theory of mind), knowledge-based inference, and comprehension monitoring in Grade 2 and again in Grade 4. Structural equation model results supported the hierarchical relations hypothesis of DIER. When a nonhierarchical, direct relations model was fitted, primarily the upper level skills (i.e., word reading and listening comprehension) were statistically significant. When hierarchical, direct, and indirect relations models were fitted, lower level skills (e.g., working memory, vocabulary) and higher order cognitive skills (e.g., perspective taking) were indirectly related to reading comprehension via multiple pathways, whereas word reading and listening comprehension remained directly related to reading comprehension. Furthermore, the magnitudes of relations varied in Grade 2 versus Grade 4 such that perspective taking (as measured by theory of mind), vocabulary, and working memory had larger effects whereas comprehension monitoring and grammatical knowledge had smaller effects on reading comprehension in Grade 4 than in Grade 2. These results provide some support for the dynamic relations hypothesis of DIER, but also suggest the complex nature of the dynamic relations as a function of development *and* text characteristics.

Educational Impact and Implications Statement

As a complex construct, reading comprehension draws on numerous language and cognitive skills. The direct and indirect effects model of reading (DIER) integrates extant prominent theoretical models and empirical evidence, and specifies structural relations among component skills—hierarchical, dynamic, and interactive relations. Findings revealed an emerging picture of structural relations, and support the importance of articulating, understanding, and examining structural relations among multiple factors.

Keywords: DIER, dynamic relations, hierarchical relations, reading comprehension

Supplemental materials: http://dx.doi.org/10.1037/edu0000407.supp

Proficient reading skills are foundational for daily functioning, academic achievement, and job performance. As such, processes and skills involved in reading have been the subject of intense inquiry in the last five decades. By now, large bodies of evidence from multiple disciplines have accumulated. However, there has been a lack of integration across lines of work. In the present study, our goal was to examine a recently proposed integrative theoretical model of reading called the direct and indirect effects model of reading (DIER; Kim, 2017b, 2019). Specifically, we examined two key hypotheses of DIER, the hierarchical relations hypothesis and the dynamic relations hypothesis (see below), using longitudinal data from English-speaking children from Grade 2 to Grade 4.

Several theoretical models (e.g., simple view of reading: Gough & Tunmer, 1986; componential model of reading: Joshi & Aaron, 2012; multicomponent view of reading: Cain, 2009; Perfetti, Landi, & Oakhill, 2005; verbal efficiency theory: Perfetti, 1985; triangle model: Adams, 1990; automaticity theory: LaBerge & Samuels, 1974) and associated evidence have revealed that numer-

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ous skills contribute to reading comprehension, including word reading, listening comprehension, phonological awareness, morphological awareness, orthographic awareness (including alphabet letter knowledge), text/oral reading fluency, working memory, attention, vocabulary, syntactic knowledge, inference, and comprehension monitoring (Adams, 1990; Adlof, Catts, & Little, 2006; Barnes, Dennis, & Haefele-Kalvaitis, 1996; Cain, Oakhill, & Bryant, 2004; Daneman & Carpenter, 1980; Elleman, Lindo, Morphy, & Compton, 2009; Foorman, Koon, Petscher, Mitchell, & Truckenmiller, 2015; Hoover & Gough, 1990; Kim, 2015a, 2017b; National Center for Family Literacy, 2008; National Institute of Child Health and Human Development [NICHD], 2000). Many of these theoretical models focused on specific aspects of reading (e.g., component skills of word reading, automaticity) and revealed detailed and rich information about focal aspects. However, without integration, they paint a partial picture. For example, a robust body of evidence indicates that phonological awareness is an important skill in word reading (National Center for Family Literacy, 2008; NICHD, 2000). What then is the nature of the role of phonological awareness in reading comprehension?

Furthermore, much of the prior work focused on identifying component skills without sufficient attention to mechanisms and structural relations among component skills. For example, a large body of studies has shown that language and cognitive skills such as working memory, vocabulary, and inference contribute to reading comprehension (e.g., Ahmed et al., 2016; Barnes et al., 1996; Cain, Oakhill, & Lemmon, 2004; Cromley & Azevedo, 2007; Daneman & Merikle, 1996; Elleman et al., 2009; Peng et al., 2018; Seigneuric & Ehrlich, 2005). Another line of work revealed that similar skills contribute to listening comprehension (e.g., Florit, Roch, & Levorato, 2014; Kendeou, Bohn-Gettler, White, & van den Broek, 2008; Kim, 2016; Kim & Phillips, 2014; Tompkins, Guo, & Justice, 2013). Then how does evidence from these lines of work fit with the simple view of reading and associated robust evidence that word reading and listening comprehension are the two key skills in reading comprehension? Similarly, working memory is related to reading comprehension as well as to its component skills such as listening comprehension (Daneman & Merikle, 1996; Florit et al., 2014; Kim & Phillips, 2014), phonological awareness (Høien-Tengesdal & Tønnessen, 2011; Swanson & Howell, 2001), vocabulary (Gathercole & Baddeley, 1990; Kim, 2017b), and inference (Cromley & Azevedo, 2007; Daugaard, Cain, & Elbro, 2017; Kim, 2016, 2017b). Then, is working memory related to reading comprehension directly, indirectly, or in both ways, and what explains these pathways?

The lack of integration and an articulation of systematic structural relations is also problematic as it ignores large bodies of evidence, albeit piecemeal and fragmented, regarding the nature of relations—for example, direct and indirect relations (Cromley & Azevedo, 2007; Cromley, Snyder-Hogan, & Luciw-Dubas, 2010; Kieffer, Biancarosa, & Mancilla-Martinez, 2013; Kim, Guo, Liu, Peng, & Yang, 2019; Vellutino, Tunmer, Jaccard, & Chen, 2007), changing relations as a function of development (e.g., Adlof et al., 2006; Kim & Wagner, 2015), text characteristics (Francis, Kulesz, & Benoit, 2018), and interactive relations (e.g., Baker, Stoolmiller, Good, & Baker, 2011; Goodwin & Ahn, 2013; Jenkins, Fuchs, van den Broek, Espin, & Deno, 2003; Katzir, Kim, & Dotan, 2018). In addition, not recognizing systematic structural relations among component skills can create confusion or incoherence in the literature. For example, some studies found the importance of vocabulary in reading comprehension (e.g., Cromley & Azevedo, 2007; Cromley et al., 2010; Elleman et al., 2009; Ouellette, 2006; Ouellette & Beers, 2010) whereas others found the lack of this relation (e.g., Braze, Tabor, Shankweiler, & Mencl, 2007; Ouellette & Beers, 2010). Similarly, the role of working memory in reading comprehension is robust in theory and evidence (see Peng et al., 2018, for a review), but some studies also found the lack of this relation (Freed, Hamilton, & Long, 2017; Van Dyke, Johns, & Kukona, 2014). DIER is an effort to address these gaps, questions, and challenges by integrating various theoretical models and associated bodies of evidence into a unifying whole (see Kim, 2019).

Direct and Indirect Effects Model of Reading (DIER)

DIER proposes that the following skills, abilities, and knowledge contribute to reading development: word reading, listening comprehension, text reading fluency, background knowledge (content knowledge and discourse knowledge), socioemotions or reading affect (e.g., motivation, attitude, self-concept, and anxiety), higher order cognitions and regulations (e.g., reasoning, inference, perspective taking, and comprehension monitoring), vocabulary, syntactic/grammatical knowledge, phonology, morphology, orthography, and domain general cognitions or executive function (e.g., working memory, attentional control; see Figure 1). These skills develop based on the interaction between child characteristics and environmental factors (see Joshi & Aaron, 2012; Kim, Boyle, Zuilkowski, & Nakamura, 2016; Snow, 2002). DIER proposes the following testable hypotheses regarding the nature of their relations: hierarchical relations, interactive relations, and dynamic relations (see Kim, 2019, for details).

DIER hypothesizes hierarchical relations among component skills such that lower level skills predict higher level skills, which, in turn, predict reading comprehension (see Figure 1); that is, lower level skills have cascading indirect, multichanneled effects on reading comprehension via higher order skills. Specifically, DIER posits that at the upper level, reading comprehension is largely a function of word reading and listening comprehension (discourse comprehension in oral language), in line with the simple view (Hoover & Gough, 1990; Tunmer & Chapman, 2012). Extending the simple view and drawing on the automaticity theory (LaBerge & Samuels, 1974) and a large body of literature (e.g., Daane, Campbell, Grigg, Goodman, & Oranje, 2005; Fuchs, Fuchs, Hosp, & Jenkins, 2001; Jenkins et al., 2003; Kim, 2015a; Kim et al., 2014; Kim, Wagner, & Lopez, 2012; Kuhn & Stahl, 2003; Riedel, 2007), DIER posits that the relations of word reading and listening comprehension to reading comprehension are mediated by text reading fluency (partial mediation for listening comprehension and complete mediation for word reading depending on the developmental phase; e.g., Kim & Wagner, 2015). Word reading and listening comprehension, in turn, are supported by their own component skills. Word reading requires knowledge of phonology, semantics (e.g., morphology), and orthography in line with the triangle model (Adams, 1990) and associated evidence (Burgess & Lonigan, 1998; Castles & Coltheart, 2004; Deacon, Kirby, & Casselman-Bell, 2009; Kim, Apel, & Al Otaiba, 2013; National Center for Family Literacy, 2008; NICHD, 2000; Torgesen, Wagner, & Rashotte, 1994; Wolter, Wood, & D'zatko, 2009). Listening comprehension draws on foundational oral lan-

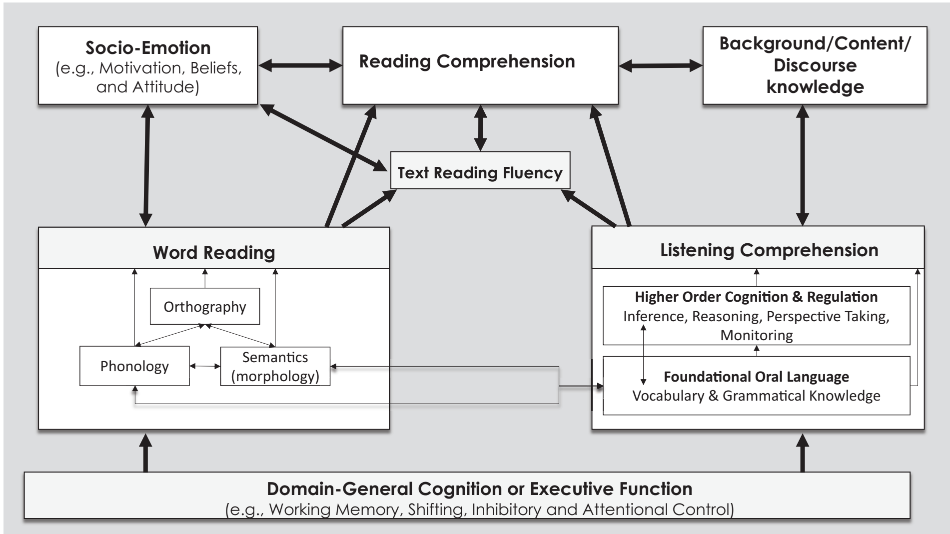

Figure 1. Direct and indirect effects model of reading (DIER). The skills are hypothesized to have hierarchical, dynamic (as a function of text characteristics and reading development), and interactive (or bidirectional) relations. Double-headed arrows represent interactive relations whereas single-headed arrows represent mostly unidirectional relations.

guage skills such as vocabulary and grammatical knowledge (including syntax and morphosyntax; Kendeou et al., 2008; Lepola, Lynch, Laakkonen, Silvén, & Niemi, 2012; Strasser & del Rio, 2014), which, in turn, are necessary for higher order cognitions such as inference, reasoning, perspective taking (including theory of mind), and comprehension monitoring (Astington & Jenkins, 1999; Carlson, Moses, & Claxton, 2004; de Villiers & Pyers, 2002; Kim, 2016; Lepola, Lynch, Kiuru, Laakkonen, & Niemi, 2016; Slade & Ruffman, 2005). These language and cognitive component skills of comprehension also have hierarchical relations shown in Figure 1 (see Kim, 2016, 2017b, for theoretical conceptualization and empirical evidence). Both the component skills of word reading and listening comprehension require domain-general cognition or executive function such as working memory and inhibitory and attentional control (see Figure 1).

DIER also posits interactive relations. Text reading fluency and reading comprehension have an interactive or bidirectional relation (Baker et al., 2011; Jenkins et al., 2003; Little et al., 2017). Reading and listening comprehension have bidirectional relations with background (content and discourse) knowledge while socioemotions related to reading (e.g., motivation, attitude, self-concept, and anxiety) have bidirectional relations with word reading, text reading fluency, and reading comprehension (Chapman & Tunmer, 2003; Katzir et al., 2018; Katzir, Lesaux, & Kim, 2009; Wigfield & Guthrie, 1997). Children's foundational oral language skills (vocabulary and grammatical knowledge) interact with knowledge of phonology and semantics (i.e., morphology; Goodwin & Ahn, 2013; Kuo & Anderson, 2006; Nagy & Anderson, 1984), and with inference (Currie & Cain, 2015; Kim, 2016, 2017a; Lepola et al., 2012).

Another key hypothesis of DIER is dynamic relations, which states that the relations of component skills (e.g., word reading and its component skills, and listening comprehension and its component skills) to reading comprehension change as a function of reading development *and* text characteristics. The changing relations as a function of reading development is because of a large constraining role of word reading in reading comprehension acting as a bottleneck at the beginning phase of reading development while listening comprehension plays an increasingly greater role with reading development (Adlof et al., 2006; Foorman et al., 2015; Kim, 2015b; Lonigan, Burgess, & Schatschneider, 2018). If word reading and listening comprehension play differential roles in reading comprehension depending on development, so would their component skills. That is, if word reading plays a larger role in the beginning phase, the relative contributions of component skills of word reading (e.g., phonological awareness, alphabet letter knowledge) to reading comprehension would be larger in the beginning phase than in a more advanced phase of reading development. Following the same logic, if listening comprehension plays a greater role in reading comprehension at a more advanced phase, the relative roles of component skills of listening comprehension, particularly vocabulary, syntactic knowledge, and higher order cognitive skills, would increase with children's reading development.

The nature of relations is also expected to differ as a function of text characteristics of comprehension tasks, including orthographic features of words (see Kim, 2019, for details).[1] Texts vary in terms of vocabulary, syntactic complexity, content, the arrangement structure of ideas, and cognitive demands (e.g., Bailey, 2007; Friedman & Miyake, 2000; Scarcella, 2008; Schleppegrell, 2001; Seigneuric & Ehrlich, 2005) and, therefore, the extent to which specific component skills contribute to comprehension would vary depending on the textual demands. For instance, texts with many

[1] Details about orthographic, phonological, and semantic features of words (Goodwin, Gilbert, Cho, & Kearns, 2014; Kearns, 2015; Kim, Petscher, & Park, 2016) and their implications in the dynamic relations hypothesis in DIER (differential demands on phonological, orthographic, and morphological processing) are beyond the scope of the present study. See Kim (2019), for details.

sophisticated vocabulary words would increase the demand of vocabulary knowledge for successful comprehension. Texts also vary in working memory demand depending on the location of relevant information in relation to focal information (Cain et al., 2004; Yuill, Oakhill, & Parkin, 1989). Although texts in upper grades typically contain advanced multisyllabic vocabulary, more syntactically complex texts, and dense information (Bailey, 2007; Scarcella, 2008; Schleppegrell, 2001), text demands also vary within same-grade-level texts. Therefore, the dynamic relations hypothesis would entail intricate interactions between development and text demands.

An important corollary of the nature of the relations of component skills to comprehension is measurement of comprehension. For example, if listening comprehension and reading comprehension are measured in a similar or equivalent manner in terms of language and cognitive demands (e.g., the passages used in reading comprehension tasks do not have significantly greater vocabulary demands than those in listening comprehension tasks; Kim, 2019), then the contributions of component skills of listening comprehension (e.g., vocabulary) to reading comprehension would be completely mediated by listening comprehension. If reading comprehension tasks (or passages) are significantly different from listening comprehension tasks in terms of language and cognitive demands, then the language and cognitive component skills would make a direct contribution to reading comprehension over and above listening comprehension. Similarly, the relations of language and cognitive skills (e.g., vocabulary, grammatical knowledge, and inference; see the right bottom of Figure 1) to listening comprehension would vary as a function of the nature of texts in listening comprehension tasks (Kim, 2016). The dynamic relations hypothesis as a function of text characteristics is in line with work on measurement of comprehension (Cutting & Scarborough, 2006; Francis, Fletcher, Catts, & Tomblin, 2005; Keenan, Betjemann, & Olson, 2008) and with recent recognition of text characteristics in reading comprehension (Francis et al., 2018).

Adding more complexity to the dynamic relations hypothesis as a function of text characteristics is that the foundational language and cognitive skills (e.g., vocabulary, grammatical knowledge, working memory, inhibitory, and attentional control) are hypothesized to make indirect contributions to reading comprehension via two pathways: listening comprehension *and* word reading. As shown in Figure 1, domain-general cognitions (e.g., working memory, attentional control) are hypothesized to be necessary for word reading and its component skills as well as for listening comprehension and its component skills. Likewise, vocabulary and grammatical knowledge are hypothesized to contribute to word reading (Bishop & Snowling, 2004) and to listening comprehension and its component skills (Kim, 2016, 2019). Therefore, the indirect effects of these foundational language and cognitive skills on reading comprehension should consider and account for their pathways via listening comprehension *and* via word reading.

The component skills and hypothesized relations of DIER—hierarchical, interactive, and dynamic relations—are based on an integration of extant work in multiple lines. Thus, DIER shares similarities with extant models, but also vitally extends them. For example, DIER integrates the simple view with the multicomponent view of reading and work on discourse comprehension, listening comprehension, text reading fluency, component skills of listening comprehension, socioemotions, and background knowledge. DIER also situates a theoretical model of word reading, the triangle model (Adams, 1990), in the contexts of reading comprehension, integrating it with evidence on text reading fluency and recognizing the relations of the component skills of word reading (e.g., phonological awareness, morphological awareness) with those of listening comprehension (e.g., vocabulary), thereby describing the nature of relations (e.g., hierarchical, interactive relations).

The hypotheses in DIER are based on integration of extant theoretical models and empirical, but piecemeal, evidence and, thus, these ideas together within DIER should undergo rigorous testing in empirical studies. For example, the hierarchical relations model (or the consequent direct and indirect relations model) can be directly compared with a nonhierarchical, direct relations model. Interactive relations can be examined using longitudinal data by investigating how focal skills are related to each other across time points after accounting for autoregressive effects (e.g., Cheng, Zhang, Wu, Liu, & Li, 2016; Kim & Piper, 2019) or how change or development in a focal skill is related to change or development in another focal skill (e.g., Ahmed, Wagner, & Lopez, 2014; Kim, Petscher, Wanzek, & Al Otaiba, 2018; Petscher, Quinn, & Wagner, 2016). Longitudinal investigations are also necessary to investigate the dynamic relations of component skills as a function of reading development (e.g., Adlof et al., 2006; Kim & Wagner, 2015). The dynamic relations as a function of text characteristics can be examined in experimental studies where text characteristics are manipulated, as well as by teasing out variances attributable to text features from individual factors (e.g., Francis et al., 2018; Goodwin, Gilbert, Cho, & Kearns, 2014).

Present Study

Examining all the hypotheses of DIER was beyond the scope of the present study. Instead, the goal of the present study was to replicate the hierarchical relations hypothesis for children in an upper elementary grade (i.e., fourth grade) and to explore the dynamic relations hypothesis of component skills as a function of reading development using longitudinal data from Grade 2 to Grade 4 (grade as a proxy for developmental phase). The hierarchical relations hypothesis of DIER has been investigated and validated for children in primary grades (Kim, 2017b, 2019). Specifically, the hierarchical relations specified in DIER fit data well for second-grade students in English (Kim, 2017b) and first-grade children learning to read Korean (Kim, 2019). In the present study, we extend this previous work by fitting and comparing a nonhierarchical, direct relations model with hierarchical relations models aligned with DIER in Grade 2 and Grade 4. The dynamic relations hypothesis, particularly the relative contributions of language and cognitive component skills using DIER as a framework, has not been explored before. Specific research questions of the present study were as follows:

1. Are the language and cognitive component skills directly related to reading comprehension in Grade 2 and Grade 4?

2. Do the hierarchical relations specified in DIER describe the data well in Grade 2 and Grade 4? If so, what is the nature of the relations of language and cognitive component skills to listening comprehen-

sion, word reading, and reading comprehension in Grade 2 and Grade 4?

3. How do the relations change from Grade 2 to Grade 4? Do the contributions of word reading, listening comprehension, and language and cognitive component skills to reading comprehension change from Grade 2 to Grade 4?

It was hypothesized that the hierarchical relations specified in DIER would fit the data well in Grade 2 and Grade 4. Listening comprehension was expected to have a stronger relation to reading comprehension in Grade 4 than in Grade 2 while an opposite pattern was expected for word reading. We also hypothesized that some language and cognitive skills might have stronger indirect relations to reading comprehension in Grade 4 than in Grade 2 via the stronger contribution of listening comprehension to reading comprehension in Grade 4. However, we did not have a specific hypothesis about which language and cognitive skills would have increased indirect effects in Grade 4 given the multiple factors (development and text features) that are expected to be involved.

Method

Participants

Data were drawn from a longitudinal study in which 165 children in Grade 2 (52% boys; mean age = 7 years 6 months) in the Southeastern United States were followed to Grade 4. Cross-sectional analyses of the data in Grade 2 combined with another cohort's data were reported previously (Kim, 2017b), but longitudinal analyses have not been reported. Percentages of White, African American, Hispanic, Asian, and mixed-race students, respectively, were as follows: 53, 34, 6, 1, and 4% in Grade 2; and 58, 32, 5, 2, and 3% in Grade 4. Approximately 68 and 67% of the children in Grade 2 and Grade 4, respectively, were eligible for free and reduced-price lunch. Attrition over the 2 years was 20% such that 132 children remained in the study in Grade 4. Multivariate analysis of variance (MANOVA) revealed no differences in the Grade 2 measured skills between those who remained in the study versus those who did not, Wilks' $\lambda = .89$, $F(12, 146) = 1.53$, $p = .12$. Exceptions were in theory of mind, comprehension monitoring, and free and reduced-price lunch status such that a greater number of children who left the study were eligible for free and reduced-price lunch (88%, compared with 68% of those who stayed in the study), and those who left the study had lower scores in Grade 2 theory of mind, $M = 6.83$ ($SD = 3.72$) versus $M = 8.54$ ($SD = 4.03$), and comprehension monitoring, $M = 6.03$ ($SD = 2.72$) versus $M = 7.39$ ($SD = 3.13$). Human subjects approval was obtained from Florida State University (HSC No. 2016.17872). Participating schools used *Imagine it!* (Bereiter, 2010) for their reading program.

Measures

Children were assessed on reading comprehension, word reading, listening comprehension, perspective taking (as measured by theory of mind), knowledge-based inference, comprehension monitoring, vocabulary, grammatical knowledge, working memory, and attention in Grade 2 and Grade 4. Unless otherwise noted, children's responses were scored dichotomously (1 = correct, 0 = incorrect) for each item, and all the items were administered to children. Reliability estimates ranged from acceptable to excellent (see Table 1).

Reading comprehension. Two normed tasks were used to measure reading comprehension: the Reading Comprehension subtest of the Wechsler Individual Achievement Test-III (WIAT-III; Wechsler, 2009) and the Passage Comprehension subtest of the Woodcock Johnson-III (WJ-III; Woodcock, McGrew, & Mather, 2001). The WIAT-III task requires the child to read narrative and expository passages and answer multiple choice comprehension questions. The WJ-III task is a cloze task where the child reads sentences and passages and fills in blanks.

Word reading. Two forms of the Sight Word Efficiency task of the Test of Word Reading Efficiency-2 (TOWRE-2; Wagner, Torgesen, & Rashotte, 2012) were administered. In these tasks, the child was asked to read words of increasing difficulty with accuracy and speed in 45 s. Note that in Grade 2, another word reading task, the Letter Word Identification of the WJ-III, was also administered but was not used in the analysis to ensure comparability of the word reading construct in Grade 2 and Grade 4.

Listening comprehension. Children's listening comprehension was assessed by (a) the Narrative Comprehension subtest of the Test of Narrative Language (TNL; Gillam & Pearson, 2004), (b) an experimental expository task, and (c) the Listening Comprehension Scale of the Oral and Written Language Scales-II (OWLS-II; Carrow-Woolfolk, 2011). In the TNL Narrative Comprehension subtest, the child heard three narrative stories and was asked open-ended comprehension questions for each story (for a total of 30 items across the three stories). Following the TNL manual, the majority of children's responses were scored using a dichotomous scale of 0 or 1, but some were scored using a trichotomous scale of 0, 1, or 2.

The experimental expository comprehension task was composed of three expository passages in each grade from the Qualitative Reading Inventory-5 (QRI-5; Leslie & Caldwell, 2011). Titles of the passages were as follows: *Changing Matter* (140 words), *Whales and Fish* (200 words), and *Where do People Live?* (282 words) in Grade 2; and *Wool: From Sheep to You* (220 words), *Plant Structures for Survival* (278 words), and *The Octopus* (254 words) in Grade 4. After listening to each passage, the child was asked comprehension questions (a total of 24 questions across the three passages).

In the OWLS–II Listening Comprehension task, the child listened to stimulus sentences and was asked to point to one of four pictures that corresponded to the heard sentences. Test administration discontinued after four consecutive incorrect items.

Perspective taking. Students' perspective taking was measured by a theory of mind task. Theory of mind is one's ability to understand others' mental states and perspectives such as thoughts, emotions, desires, and beliefs (Wellman, Cross, & Watson, 2001) and, thus, was used in the present study to measure children's perspective taking skill. Studies have shown that first-order theory of mind develops around age 4 (Wellman et al., 2001) while second-order theory of mind develops around age 5 to 7 (Perner & Wimmer, 1985; Sullivan, Zaitchik, & Tager-Flusberg, 1994). Thus, considering the developmental phases of children, three second-order scenarios were used each in Grades 2 and 4 (Kim,

Table 1
Descriptive Statistics

Variable	Grade 2					Grade 4				
	α	*M* (*SD*)	Min-Max	Skew	Kurtosis	α	*M* (*SD*)	Min-Max	Skew	Kurtosis
WIAT reading comp	.82	25.83 (7.61)	0–40	−.53	−.03	.79	25.89 (7.59)	0–38	−.74	.26
WIAT reading comp SS	—	96.58 (13.23)	40–136	−.20	1.92	—	95.34 (12.18)	50–121	−.64	1.37
WJ passage comp	.82	22.97 (4.23)	12–33	.27	−.54	.82	28.02 (4.16)	13–37	−.67	.58
WJ passage comp SS	—	96.36 (11.23)	57–119	−.55	.80	—	94.70 (12.48)	42–124	−.75	1.92
Sight word efficiency 1	.90[a]	50.99 (11.94)	18–73	−.33	−.63	.91[a]	64.20 (11.16)	26–87	−.60	1.10
Sight word efficiency 1 SS	—	97.39 (15.38)	55–128	−.39	−.10	—	94.74 (14.32)	55–130	.00	.22
Sight word efficiency 2	.90[a]	51.55 (11.71)	17–78	−.24	−.35	.91[a]	64.90 (11.11)	28–89	−.49	.66
Sight word efficiency 2 SS	—	98.00 (15.50)	55–131	−.30	.00	—	95.85 (14.18)	55–132	.03	.09
TNL comp	.75	26.47 (4.95)	13–36	−.49	.07	.70	30.45 (4.25)	14–39	−.98	1.81
TNL comp SS	—	8.65 (3.07)	1–15	.03	−.15	—	9.86 (3.27)	1–18	−.06	−.32
Expository comp	.72	10.25 (3.49)	2–20	.46	.002	.70	6.52 (3.03)	0–14	.14	−.57
OWLS comp	.94	76.90 (12.89)	37–103	−.17	−.54	.92	90.42 (11.50)	44–112	−.91	1.49
OWLS com SS	—	98.41 (14.32)	44–124	−.55	.42	—	97.88 (16.13)	40–128	−.89	1.13
Theory of mind	.71	8.22 (4.02)	0–17	−.04	−.72	.81	10.23 (3.97)	0–17	−.30	−.62
CASL inference	.91	10.81 (6.92)	0–31	.67	−.38	.92	17.89 (8.74)	0–40	−.04	−.76
CASL inference SS	—	92.32 (13.15)	56–127	.34	.03	—	91.52 (17.08)	40–132	−.37	.07
Comp monitoring	.67	7.14 (3.09)	1–16	.15	−.62	.78	8.27 (2.98)	2–18	.38	.40
WJ vocabulary	.71	20.54 (2.87)	13–28	−.13	.27	.65	23.08 (2.74)	16–30	.00	−.12
WJ vocabulary SS	—	97.58 (10.52)	66–126	−.14	.55	—	95.84 (9.55)	69–120	−.07	.25
CASL grammaticality	.94	33.63 (12.46)	3–66	.23	.21	.95	43.55 (13.75)	10–84	.06	.36
CASL grammaticality SS	—	97.01 (13.43)	51–134	−.25	1.33	—	94.53 (15.89)	54–159	.52	2.18
Working memory	.70	7.94 (3.96)	0–20	.08	.35	.74	11.26 (4.36)	0–26	.15	.97
Attention	.98	118.43 (34.69)	36–210	.50	.51	.99	125.28 (37.19)	30–210	.32	−.01

Note. Min = minimum; Max = maximum; Skew = skewness; WIAT = Wechsler Individual Achievement Test, third edition; comp = comprehension; SS = standard score; WJ = Woodcock Johnson, third edition; TNL = Test of Narrative Language; OWLS = Oral and Written Language Scales, second edition; CASL = Comprehensive Assessment of Spoken Language; Inference = knowledge-based inference. Unless otherwise noted, values are raw scores.
[a] Alternate form reliability (see Table 2).

2017b). Second-order scenarios examine the child's ability to infer a story character's mistaken belief about another character's knowledge (e.g., John may think, "Aaron believes that Jane knows that there is a bake sale"; see Arslan, Hohenberger, & Verbrugge, 2017) and, therefore, taps one's complex reasoning skill, particularly related to perspectives. The three scenarios involved the context of a bake sale, visit to a farm, and going out for a birthday celebration. These scenarios were presented with a series of illustrations, followed by questions. There were six questions per scenario for a total of 18 questions.

Knowledge-based inference. Knowledge-based inference (the ability to infer information based on background knowledge) was measured by the Inference task of the Comprehensive Assessment of Spoken Language (CASL; Carrow-Woolfolk, 1999). In this task, after hearing one- to three-sentence scenarios, the child was asked a question that required inference drawing on background knowledge. For instance, the child heard "*Mandy wanted to wear last year's dress to school one day, but when she tried it on, she could not wear it. Why?*" The correct responses must reference the fact that Mandy has grown or the dress does not fit anymore. Test administration discontinued after five consecutive incorrect items.

Comprehension monitoring. Comprehension monitoring was measured by an inconsistency detection task (e.g., Cain et al., 2004; Kim & Phillips, 2014; also see Baker, 1984). The child heard a short scenario and was asked to identify whether the story made sense or not. If the child indicated that the story did not make sense, she was asked to provide a brief explanation and to fix the story so that it made sense. The meaning of *not making sense* was explained as sentences not going together in practice items. There were two practice items and nine experimental items. Consistent (three items) and inconsistent stories (six items) were randomly ordered. For all nine items, accuracy of the child's answer about whether a scenario was consistent or inconsistent was dichotomously scored. For the six inconsistent stories, the accuracy of children's explanation and repair of the story were also dichotomously scored for each item. If the child correctly responded to an inconsistent story, the total maximum possible score for the item was 3—one for correctly identifying inconsistency, one for providing a correct explanation, and one for an accurate repair; thus, the total possible score was 21. Note that the correlation of the score accounting for the repair versus not was extremely high and, therefore, the score accounting for the repair was used in the study (see Kim, 2017b).

Vocabulary. The Picture Vocabulary subtest of the WJ-III (Woodcock et al., 2001) was used. In this task, the child was asked to identify pictured objects. Test administration discontinued after six consecutive incorrect items.

Grammatical knowledge. The Grammaticality Judgment task of CASL (Carrow-Woolfolk, 1999) was used. The child was asked whether a heard sentence was grammatically correct. If grammatically incorrect, the child was asked to correct the sentence. Test administration discontinued after five consecutive incorrect items.

Working memory. A listening span task (Daneman & Merikle, 1996; Kim, 2015a, 2016) was used to measure working memory. In this task, the child was presented with a short sentence involving common knowledge familiar to children (e.g., Birds can fly) and was asked to identify whether the heard sentence was correct or not. After hearing multiple sentences (i.e., two to four), the child was asked to identify the last word of each sentence. There were four practice items and 13 experimental items. Children's yes/no responses regarding the veracity of the statement were not scored, but their responses on the last words in correct order were given a score of 0 to 2: correct last words in correct order were given 2 points, correct last words in incorrect order were given 1 point, and incorrect last words were given 0 point. The total possible score was 26. Testing discontinued after three incorrect responses.

Attention. The Strengths and Weaknesses of ADHD Symptoms and Normal Behavior Scale (SWAN; Swanson et al., 2006; see Arnett et al., 2013 for validity evidence) was used to measure children's behavioral attentiveness (e.g., "Engages in tasks that require sustained mental effort"). SWAN is a behavioral checklist that includes 30 items that are rated on a 7-point scale ranging from 1 (*far below average*) to 7 (*far above average*) to allow for ratings of relative strengths (above average) as well as weaknesses (below average). Higher scores represent greater attentiveness. Participating children's teachers completed the SWAN checklist.

Procedure

Rigorously trained research assistants worked with children individually in a quiet space in the school. The assessment battery was administered in several sessions with each Session 30 to 40 min long. The order of assessments was identical in both grades and was as follows: OWLS-II listening comprehension, working memory, WJ-III Picture Vocabulary, TNL, CASL Grammaticality Judgment, CASL Inference, experimental expository listening comprehension (QRI), theory of mind, comprehension monitoring, TOWRE-2, WJ-III Passage Comprehension, and WIAT-III Reading Comprehension.

Data Analysis Strategy

Primary data analytic strategies were Confirmatory Factor Analysis and Structural Equation Modeling, using M*plus* 7.4 (Muthen & Muthen, 2013) and the full information maximum likelihood estimator. Latent variables were created for listening comprehension, word reading, and reading comprehension whereas observed variables were used for the other language and cognitive skills because they were assessed by single measures for each construct. Measurement invariance for latent variables was examined following procedures for multigroup analysis (see Brown, 2006; Thompson & Green, 2006, for details).

The first research question was addressed by fitting a nonhierarchical, direct relations model where all the component skills (word reading, listening comprehension, theory of mind, inference, comprehension monitoring, vocabulary, grammatical knowledge, working memory, and attention) were direct predictors of reading comprehension. To address the second and third research questions, four structural equation models that hypothesize hierarchical relations aligned with DIER (see Figure 2) were fitted to the data. The four competing models differed in terms of the direct relations of language and cognitive component skills to reading comprehension. In Figure 2a, listening comprehension and word reading were hypothesized to completely mediate the relations of language and cognitive skills to reading comprehension. In Figures 2b to 2d, higher order cognitive skills (theory of mind, inference, and comprehension monitoring), foundational oral language skills (vocabulary, grammatical knowledge), and domain-general cognitive skills (working memory, attention) were, respectively, hypothesized to have direct relations to reading comprehension over and above listening comprehension and word reading. Model fits for nested models (i.e., the four alternative models, Figure 2a–d) were compared using χ^2 tests.

Model fits were evaluated by chi-square statistics, the comparative fit index (CFI), the Tucker-Lewis Index (TLI), root mean square error of approximation (RMSEA), and standardized root mean square residuals (SRMR). Typically, RMSEA values below .08, CFI and TLI values equal to or greater than .95, and SRMR equal to or less than .05 indicate an excellent model fit, and TLI and CFI values greater than .90 are considered to be acceptable (Kline, 2005).

Results

Descriptive Statistics and Preliminary Analysis

Descriptive statistics including the mean, *SD*, minimum, maximum, skewness, and kurtosis of each variable are shown in Table 1. Children's mean performances on the normed tasks (i.e., reading comprehension, word reading, listening comprehension, inference, vocabulary, and grammatical knowledge) were in the low-average to average range ($91.52 \leq Ms \leq 98.41$, and $8.65 \leq Ms \leq 9.86$ for TNL, which is on the scale of $M = 10$, $SD = 3$). Distributional properties of the variables were appropriate as indicated by skewness (± 2) and kurtosis values (<7; West, Finch, & Curran, 1995). Subsequent analysis was conducted using raw scores.

Bivariate correlations between measures in each grade are displayed in Table 2. Strengths of relations are described following a modified Evans' (1996) guidelines ($.0 \leq rs \leq .29$ as weak relations; $.30 \leq rs \leq .59$ as moderate relations; $.60 \leq rs \leq .79$ as strong relations; and $rs \geq .80$ as very strong relations). Word reading tasks ($.90 \leq rs \leq .91$) and reading comprehension ($.63 \leq rs \leq .70$) were very strongly and strongly related with each other in each grade. Listening comprehension tasks were moderately related to each other in each grade ($.37 \leq rs \leq .59$). Higher order cognitions, vocabulary, grammatical knowledge, working memory, and attentional control were all weakly to strongly related to listening comprehension and reading comprehension tasks in both grades ($.26 \leq rs \leq .57$ in Grade 2 and $.21 \leq rs \leq .62$ in Grade 4). Word reading tasks were moderately to strongly related to reading comprehension ($.48 \leq rs \leq .64$ in Grade 2 and $.37 \leq rs \leq .52$ in Grade 4) and so were listening comprehension tasks and reading comprehension ($.31 \leq rs \leq .47$ in Grade 2 and $.46 \leq rs \leq .63$ in Grade 4). Listening comprehension and language and cognitive skills had no relations or moderate relations with word reading tasks ($-.02 \leq rs \leq .36$ in Grade 2 and $.07 \leq rs \leq .44$ in Grade 4).

The extent to which confirmatory factor models measuring listening comprehension, word reading, and reading comprehension exhibited measurement invariance between Grade 2 and Grade 4 was examined. The configural model had an excellent fit: $\chi^2(62) = 82.06$, $p = .05$; CFI = .99; TLI = .98; RMSEA = .044 [.007–.068]; and SRMR = .045. The metric model where factor loadings were constrained to be the same across the grades also had an excellent fit: $\chi^2(66) = 84.82$, $p = .06$; CFI = .99; TLI =

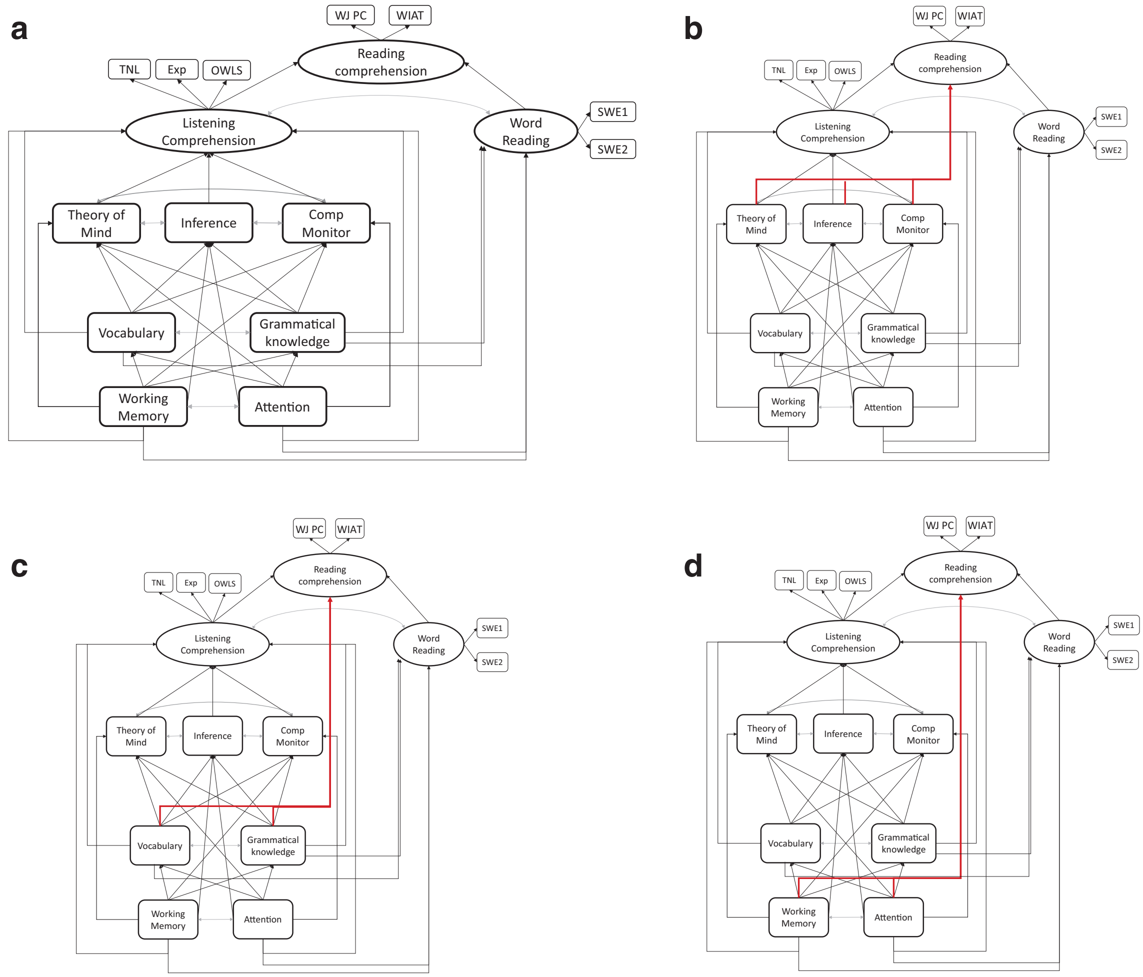

Figure 2. Four alternative models of direct and indirect effects model of reading (DIER) that were fitted in Grade 2 and Grade 4, respectively. WJ PC = Woodcock Johnson, third edition, passage comprehension; WIAT = Wechsler Individual Achievement Test, third edition; TNL = Test of Narrative Language; EXP = experimental expository task; OWLS = Listening Comprehension Scale of Oral and Written Language Scales, second edition; SWE = Sight Word Efficiency; Comp Monitor = comprehension monitoring. See the online article for the color version of this figure.

.98; RMSEA = .042 [.00–.066]; and SRMR = .053. These models did not differ in terms of model fit, $\Delta\chi^2 = 2.76$, $\Delta df = 4$, $p = .59$; therefore, in subsequent analyses, loadings of indicators to latent variables were fixed to be identical across the grades. Bivariate correlations between latent variables are shown in Table 3. In Grade 2, both listening comprehension (.73) and word reading (.76) were fairly strongly and similarly related to reading comprehension whereas in Grade 4, listening comprehension had a strong relation (.92) and word reading had a moderate relation (.57) with reading comprehension. Furthermore, listening comprehension (.96), word reading (.86), and reading comprehension (.83) had strong stabilities between Grade 2 and Grade 4.

Research Question 1: Nonhierarchical Direct Relations Model

The nonhierarchical direct relations model had a good fit to the data: $\chi^2(90) = 132.41$, $p = .002$; CFI = .97; TLI = .96; RMSEA = .056 [.034–.076]; and SRMR = .073. However, the vast majority of the variables were not statistically significant because of correlations among exogenous variables (i.e., multicollinearity). Exceptions were word reading (.66, $p < .001$) in Grade 2, and word reading (.25, p = 003), listening comprehension (1.00, $p < .001$), and attention (.23, $p = .006$) in Grade 4. Note that in Grade 4, listening comprehension had a suppression effect such that the standardized coefficient (1.00) was stronger than that in bivariate correlation (.92), most likely because of multicollinearity.

Research Question 2: Hierarchical Relations Model

To examine the hierarchical relations hypothesis, four variations of hierarchical relations models (shown in Figure 2) were fitted to the data. All the models fit the data well (see Table 4). When the Figure 2a model was compared with the Figure 2b to 2d models, the Figure 2a model did not differ from the Figure 2c or Figure 2d models, whereas the Figure 2b model had a slightly better fit than

Table 2
Bivariate Correlations Between Variables

Grade 4\Grade 2	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. WIAT reading comp	—	.63	.53	.48	.42	.41	.32	.37	.37	.27	.41	.52	.34	.40
2. WJ passage comp	.70	—	.64	.62	.44	.47	.31	.37	.35	.36	.44	.52	.39	.49
3. Sight word efficiency 1	.37	.51	—	.91	.18	.21	.03[a]	.08[a]	.15	.12[a]	.26	.36	.23	.35
4. Sight word efficiency 2	.38	.52	.90	—	.06[a]	.18	−.02[a]	.03[a]	.07[a]	.05[a]	.17	.30	.22	.36
5. TNL comp	.63	.62	.34	.28	—	.59	.44	.45	.55	.47	.42	.57	.33	.32
6. Expository comp	.60	.49	.13[a]	.17	.53	—	.37	.51	.51	.40	.36	.52	.32	.40
7. OWLS comp	.49	.46	.16[a]	.12[a]	.56	.44	—	.36	.42	.26	.46	.43	.33	.28
8. Theory of mind	.53	.45	.10[a]	.07[a]	.62	.55	.43	—	.41	.33	.34	.29	.24	.33
9. CASL inference	.57	.55	.25	.28	.56	.50	.52	.47	—	.41	.45	.55	.20	.28
10. Comp monitoring	.39	.34	.21	.17	.40	.40	.31	.41	.43	—	.22	.41	.15	.35
11. WJ vocabulary	.53	.58	.15[a]	.21	.44	.51	.45	.30	.55	.31	—	.45	.35	.22
12. CASL grammaticality	.55	.53	.28	.31	.47	.45	.49	.31	.60	.34	.50	—	.37	.35
13. Working memory	.43	.41	.13[a]	.17	.42	.30	.42	.37	.36	.21	.26	.35	—	.36
14. Attention	.45	.52	.39	.44	.33	.26	.21	.29	.27	.34	.15[a]	.31	.30	—

Note. WIAT = Wechsler Individual Achievement Test, third edition; comp = comprehension; WJ = Woodcock Johnson, third edition; TNL = Test of Narrative Language; OWLS = Oral and Written Language Scales, second edition; CASL = Comprehensive Assessment of Spoken Language; Inference = knowledge-based inference. Values above diagonal are for Grade 2 and those below diagonal are for Grade 4. All coefficients are statistically significant at $p < .05$ except for those indicated by [a].

the Figure 2a model (see Table 4). However, the Figure 2b model had a Heywood case and a suppressor effect of Grade 4 theory of mind on Grade 4 reading comprehension. Therefore, the most parsimonious Figure 2a model was selected as the final model. In other words, listening comprehension and word reading completely mediated the relations of language and cognitive skills to reading comprehension in Grades 2 and 4.

Standardized coefficients of the Figure 2a model are presented in Figure 3. In Grade 2 (Figure 3a), both listening comprehension (.60, $p < .001$) and word reading (.64, $p < .001$) had strong relations to reading comprehension whereas in Grade 4 (Figure 3b), listening comprehension (.82, $p < .001$) had a very strong relation and word reading had a moderate relation (.32, $p < .001$). The relations of language and cognitive skills to listening comprehension and word reading were similar in Grades 2 and 4, but there were also some differences. Overall, higher order cognitive skills were independently related to listening comprehension after accounting for the other language and cognitive skills. An exception was comprehension monitoring to listening comprehension in Grade 4 (.02, $p = .68$). Furthermore, the foundational language (vocabulary and grammatical knowledge) and cognitive skills (working memory and attention) were directly and indirectly related to listening comprehension in both grades with an exception of attention in Grade 2 (.09, $p = .12$). The relations of foundational language and cognitive skills to word reading were also similar such that grammatical knowledge and attention were uniquely related whereas working memory and vocabulary were not. Note that the magnitude of the relation of grammatical knowledge to word reading (.18, $p = .06$) in Grade 4 was similar to that in Grade 2 (.20, $p = .02$), but did not reach conventional statistical significance at the .05 level.

Table 3
Correlations Between Latent Variables in Grade 2 and Grade 4

Latent variables	G2 listening comprehension	G2 word reading	G2 reading comprehension
G2 listening comprehension	—		
G2 word reading	.19	—	
G2 reading comprehension	.73	.76	—
	G4 listening comprehension	G4 word reading	G4 reading comprehension
G4 listening comprehension	—		
G4 word reading	.32	—	
G4 reading comprehension	.92	.57	—
	G2 listening comprehension	G2 word reading	G2 reading comprehension
G4 listening comprehension	.96	.30	.76
G4 word reading	.25	.86	.66
G4 reading comprehension	.83	.50	.83

Note. All the coefficients are statistically significant at the $p < .05$ level.

The relations of foundational language and cognitive skills to higher order cognitions also were similar across the grades with some differences. For theory of mind, vocabulary (.23, $p = .005$) and attention (.23, $p = .003$) were directly related to it in Grade 2 while in Grade 4, working memory (.26, $p = .002$) and attention (.17, $p = .04$) were uniquely related to theory of mind. For knowledge-based inference, vocabulary and grammatical knowledge were independently related to it but working memory and attention were not in both grades. For comprehension monitoring, grammatical knowledge (.34, $p < .001$) and attention (.25, $p = .001$) were uniquely related to it in Grade 2 whereas in Grade 4, vocabulary (.18, $p = .045$) and attention (.26, $p = .002$) were. Across the grades, vocabulary was independently predicted by working memory but not by attention while grammatical knowledge was predicted by both working memory and attention.

The included variables explained large amounts of variance in listening comprehension and reading comprehension in both grades: .86 in listening comprehension and .95 in reading comprehension in Grade 2, and .88 in listening comprehension and .95 in reading comprehension in Grade 4. The amount of variance in word reading explained by vocabulary, grammatical knowledge,

Table 4
Model Fit Comparisons

Figure	$\chi^2(df)$, p value	CFI (TLI)	RMSEA [90% CI]	SRMR	Model comparison: $\Delta\chi^2(\Delta df$, p value)
Figure 2a	150.07 (104), .002	.98 (.96)	.055 [.034, .073]	.055	
Figure 2b	136.81 (98), .006	.98 (.97)	.052 [.029, .071]	.055	1a vs. 1b: 13.26 (6, .04)
Figure 2c	146.22 (100), .002	.98 (.96)	.056 [.035, .075]	.055	1a vs. 1c: 3.85 (4, .42)
Figure 2d	143.69 (100), .003	.98 (.96)	.055 [.033, .073]	.054	1a vs. 1d: 6.38 (4, .17)

Note. CI = confidence interval; CFI = comparative fit index; RMSEA = root mean square error of approximation; SRMR = standardized root mean square residual.

working memory, and attention was somewhat small: .19 in Grade 2 and .23 in Grade 4. This is not surprising given that the key component skills of word reading related to phonological, orthographic, and morphological processing were not included in the present study.

Research Question 3: Dynamic Relations

To examine whether the contributions of component skills to reading comprehension vary in Grade 2 versus Grade 4, total effects (both direct and indirect effects in terms of standardized regression weights) of the component skills on listening comprehension and reading comprehension were estimated. As shown in Table 5, all the component skills made substantial total contributions to listening comprehension and reading comprehension, ranging from .10 to .82. For example, the domain-general cognitive skills (working memory and attention) had substantial total effects on listening comprehension (.33 to .45) and subsequently on reading comprehension (.29 to .43), and their effects were primarily indirect via vocabulary, grammatical knowledge, theory of mind, inference, and comprehension monitoring. An exception in substantial total effects was comprehension monitoring in Grade 4, which had a negligible total effect of .02.

When comparing results in Grade 2 versus Grade 4, a few differences are notable. First, the direct effects of listening comprehension and word reading to reading comprehension differed such that the magnitudes were similar in Grade 2, but in Grade 4, the magnitude increased for listening comprehension from .60 to .82 while it decreased for word reading from .64 to .32. Second, the magnitudes of the total effects of theory of mind, vocabulary, and working memory on reading comprehension increased by .10 or more between Grades 2 and 4; in contrast, the magnitude decreased for comprehension monitoring (from .10 to .02) and grammatical knowledge (from .41 to .28).

Discussion

Our goal in this study was to replicate the hierarchical relations hypothesis and to explore the dynamic relations hypothesis as a function of reading development in the context of DIER. The hierarchical relations hypothesis states that the component skills of reading comprehension have multiple layers of hierarchical relations where higher order skills are directly related to reading comprehension, and lower level skills support higher order skills, and thus, component skills have direct and indirect relations among themselves and to reading comprehension. The dynamic relations hypothesis states differential contributions of component skills to reading comprehension as a function of reading development and text characteristics.

Hierarchical Relations of Component Skills

To examine the hierarchical relations hypothesis, a direct relations model and four alternative hierarchical DIER models were fitted to the data in Grades 2 and 4. In the direct relations model, all the component skills were hypothesized to be direct predictors of reading comprehension. In the hierarchical models, the component skills were hypothesized to have hierarchical relations according to DIER (see Figure 2a to 2d). Results showed that the direct relations model fit the data well. However, the vast majority of component skills were not statistically significant in both grades, and listening comprehension had a suppression effect in Grade 4, because of multicollinearity. When four variations of the hierarchical relations models were compared, the complete mediation model (Figure 2a) fit the data best in Grades 2 and 4. Overall, the included component skills explained the vast majority of variance in reading comprehension (95%) and in listening comprehension (over 85%).

The results support the hierarchical relations and consequent direct and indirect nature of relations as hypothesized by DIER. When structural relations were not specified in a direct relations model, the vast majority of component skills were not statistically significant. The direct relations approach (in theory or data analysis) is useful in isolating unique or independent skills, but masks structural relations among component skills. On the contrary, DIER hypothesizes hierarchical relations. In the present study, we found that word reading and listening comprehension completely mediated the relations of a relatively comprehensive set of language and cognitive skills to reading comprehension. Furthermore, listening comprehension was predicted by higher order cognitive skills (i.e., perspective taking as measured by theory of mind, knowledge-based inference, and comprehension monitoring), foundational language skills (vocabulary and grammatical knowledge), and domain-general cognitions. Higher order cognitive skills were predicted by vocabulary and grammatical knowledge, which, in turn, were predicted by working memory and attention. The foundational language and cognitive skills, grammatical knowledge and attention in particular, also independently predicted word reading.

The hierarchical and mediated relations according to DIER entail cascading upward indirect effects of low-level skills on higher level skills. In this study, indirect effects of component skills on listening comprehension and reading comprehension were substantial for the most part, but it was marked for low-order

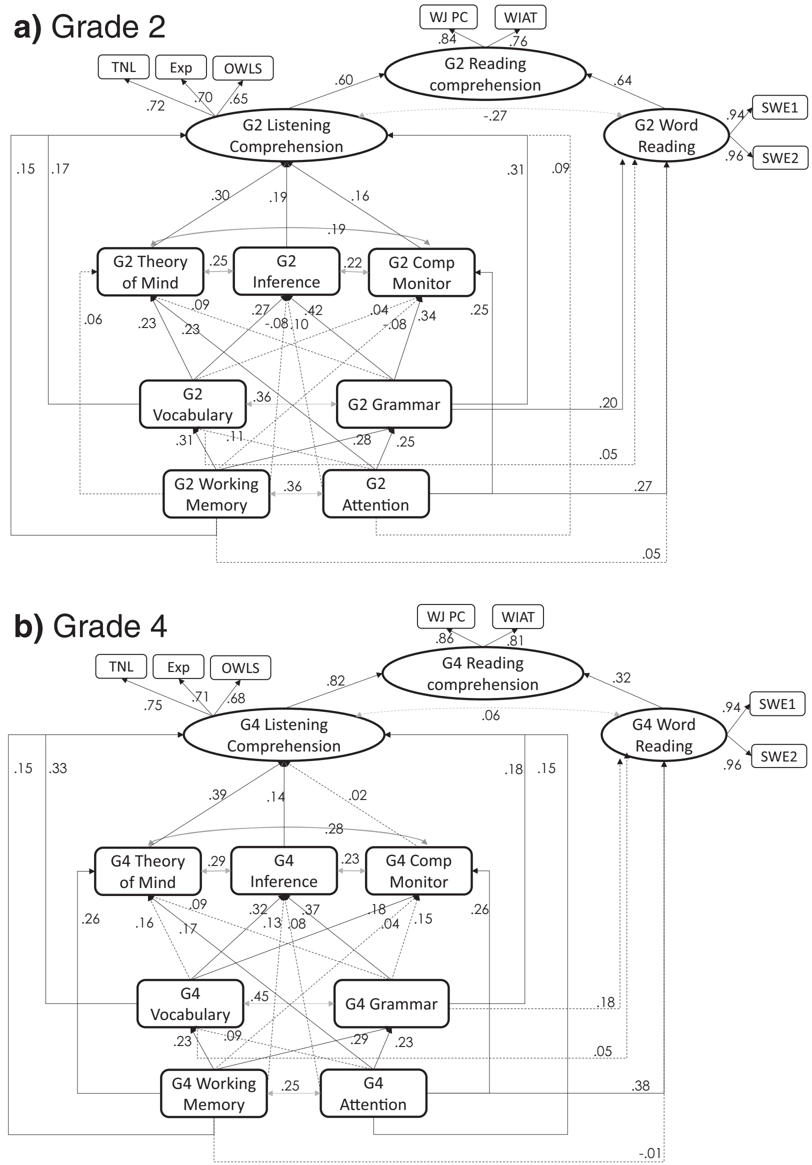

Figure 3. Standardized structural regression weights for the direct and indirect effects model of text comprehension for (a) Grade 2 and (b) Grade 4. Two-sided arrows represent covariances. Solid paths are statistically significant at $p < .05$; dashed paths are not statistically significant. WJ PC = Woodcock Johnson, third edition, passage comprehension; WIAT = Wechsler Individual Achievement Test, third edition; TNL = Test of Narrative Language; EXP = experimental expository task; OWLS = Listening Comprehension Scale of Oral and Written Language Scales, second edition; SWE = Sight Word Efficiency; Comp Monitor = comprehension monitoring.

or foundational skills. For instance, attention and working memory had relatively small direct effects on listening comprehension, and their contributions to reading comprehension were completely mediated by word reading and listening comprehension. However, their indirect effects via vocabulary, grammatical knowledge, and higher order cognitive skills were substantial, and their total effects on listening comprehension and reading comprehension were large (see Table 5). These results are in line with recent studies (Kim, 2016, 2019) and a large body of previous, albeit piecemeal, studies indicating that foundational oral language and domain-general cognitive skills predict higher order skills (e.g., theory of mind; Arslan et al., 2017; Carlson, Moses, & Breton, 2002; de Villiers & Pyers, 2002; Slade & Ruffman, 2005). The relations of foundational language and cognitive skills to theory of mind differed such that in Grade 2, vocabulary completely mediated the relation of working memory to theory of mind whereas in Grade 4, working memory made a direct contribution to theory of mind over and above vocabulary, attention, and grammatical knowledge. Explanations for these differences are beyond the scope of the present study, but it might be that with development of vocabulary from

Table 5
Direct, Indirect, and Total Effects (Standardized Regression Weights and SEs) of Language and Cognitive Component Skills on Listening Comprehension and Reading Comprehension in Grade 2 and Grade 4, Respectively

Variable	Grade 2 listening comprehension			Grade 2 reading comprehension		
	Direct effect (*SE*)	Indirect effect (*SE*)	Total effect (*SE*)	Direct effect (*SE*)	Indirect effect (*SE*)	Total effect (*SE*)
G2 listening comp	NA	NA	NA	.60 (.05)	NA	.60 (.05)
G2 word reading	NA	NA	NA	.64 (.06)	NA	.64 (.06)
G2 theory of mind	.30 (.06)	NA	.30 (.06)	NA	.18 (.04)	.18 (.04)
G2 inference	.19 (.06)	NA	.19 (.06)	NA	.11 (.04)	.11 (.04)
G2 comp monitoring	.16 (.06)	NA	.16 (.06)	NA	.10 (.04)	.10 (.04)
G2 vocabulary	.17 (.06)	.13 (.04)	.29[a] (.07)	NA	.21 (.06)	.21 (.06)
G2 grammar	.31 (.07)	.16 (.05)	.48[a] (.07)	NA	.41 (.06)	.41 (.06)
G2 working memory	.15 (.06)	.21 (.06)	.36 (.08)	NA	.29 (.07)	.29 (.07)
G2 attention	.09 (.06)	.28 (.06)	.37 (.08)	NA	.43 (.07)	.43 (.07)
	Grade 4 listening comprehension			Grade 4 reading comprehension		
G4 listening comp	NA	NA	NA	.82 (.03)	NA	.82 (.03)
G4 word reading	NA	NA	NA	.32 (.07)	NA	.32 (.07)
G4 theory of mind	.39 (.06)	NA	.39 (.06)	NA	.32 (.05)	.32 (.05)
G4 inference	.14 (.07)	NA	.14 (.07)	NA	.12 (.06)	.12 (.06)
G4 comp monitoring	.02 (.06)	NA	.02 (.06)	NA	.02 (.05)	.02 (.05)
G4 vocabulary	.33 (.06)	.11 (.04)	.44 (.07)	NA	.38 (.06)	.38 (.06)
G4 grammar	.18 (.06)	.09 (.05)	.27 (.07)	NA	.28 (.07)	.28 (.07)
G4 working memory	.15 (.05)	.30 (.06)	.45 (.07)	NA	.39 (.07)	.39 (.07)
G4 attention	.15 (.06)	.18 (.06)	.33 (.08)	NA	.41 (.07)	.41 (.07)

Note. Comp = comprehension.
[a] Because of rounding.

Grade 2 to Grade 4, the vocabulary demand of theory of mind is decreased in Grade 4, and, as a consequence, individual differences in working memory explain children's performance in theory of mind over and above vocabulary and other skills.

These results, combined with extant evidence from multiple lines of work, underscore the importance of articulating structural relations among component skills and the pathways of their relations, as well as consequent direct and indirect relations in a theoretical model of reading. Much of prior work expended efforts on identifying component skills and their direct effects although recent efforts started addressing structural relations (e.g., Cromley & Azevedo, 2007; Vellutino et al., 2007). DIER expands these existing multiple lines of work and theories by integrating them into a single model that specifies hierarchical relations (see Figure 1).

Dynamic Relations as a Function of Reading Development

The dynamic relations hypothesis was partially supported. The differential contributions of listening comprehension and word reading to reading comprehension were supported (see Figure 3). In Grade 2, both listening comprehension and word reading had strong relations to reading comprehension with similar magnitudes (.60 and .64). In Grade 4, in contrast, listening comprehension was very strongly related to reading comprehension (.82) whereas word reading was moderately related (.32). These results are in line with previous studies, which showed an increasing role of listening comprehension in reading comprehension as children develop reading skills (Adlof et al., 2006; Foorman et al., 2015; Kim, 2015b; Kim & Wagner, 2015; Lonigan et al., 2018). Beyond this, though, the present findings indicate a complex picture about the dynamic relations hypothesis when it comes to the relations of component skills of word reading and listening comprehension to reading comprehension.

First, we found a differential pattern for higher order cognitions such that the total indirect effect of perspective taking (as measured by theory of mind) on reading comprehension increased from .18 to .32 between Grades 2 and 4, the total indirect effect of knowledge-based inference remained similar (.11 in Grade 2 and .12 in Grade 4), and the total indirect effect of comprehension monitoring decreased from .10 to .02 (see Table 5). The larger total effect of theory of mind on reading comprehension in Grade 4 appears to have been driven by its stronger relation to listening comprehension (see Table 2 for bivariate correlations; also see Figure 3) as well as the stronger relation of listening comprehension to reading comprehension. As noted above, theory of mind is one's ability to understand others' perspectives, requiring complex reasoning skills. Although theory of mind is widely recognized as a social reasoning ability, it might be that a complex reasoning skill captured in theory of mind (particularly the second-order theory of mind) plays an increasing role in discourse comprehension (i.e., listening comprehension in the present study) with development rather than a specific social aspect per se. Reasoning is a broad construct including various taxonomies (deductive, inductive) and aspects (e.g., relational, analogical, and visuospatial reasoning). DIER includes reasoning as part of higher order cognitive skills, in addition to specific types of reasoning skills such as inference and perspective taking, to highlight the roles of inference and perspective taking (as measured by theory of mind) given the large body of literature and theoretical models (e.g., Dore, Amendum, Golinkoff, & Hirsh-Pasek, 2018; Kim, 2016; van den Broek, Rapp, & Kendeou, 2005), and at the same time to acknowledge the roles of other types of reasoning skills in comprehension. One such example is visuospatial reasoning, which would be particularly important for constructing accurate mental representations for texts with greater spatial reasoning demands (e.g., in terms of text content and texts with graphs or visual presentations; see, e.g., Friedman & Miyake, 2000; Gattis & Holyoak, 1996).

Alternatively, the present results may be because of text differences in each grade—that is, texts in Grade 4 may have required a greater extent of perspective taking and/or complex reasoning captured in theory of mind. Evidence from the bivariate relations (see Table 2) suggests that the present findings are likely because of the former (increased importance of theory of mind in discourse comprehension with development). Recall that two of the three listening comprehension tasks (the TNL task and the OWLS task) were identical in both grades whereas different passages were used in the expository texts in Grade 2 versus Grade 4. If the findings were primarily driven by text characteristics, a change in correlation coefficient would be expected between theory of mind and comprehension of expository texts. As shown in Table 2, however, there was a large change in theory of mind's relation with the TNL task (from .45 to .62) whereas its relation with the expository task barely changed (from .51 to .55) and the change in its relation with the OWLS task was relatively small from .36 to .43 between Grades 2 and 4. Thus, these results suggest that children's development likely explains the stronger relation of theory of mind to listening comprehension in Grade 4.

Additionally, the results for comprehension monitoring and knowledge-based inference appear to have been driven by the increased role of theory of mind in combination with the shared variance among theory of mind, knowledge-based inference, and comprehension monitoring, as well as the use of a model that accounted for other language and cognitive skills. In other words, bivariate correlations (see Table 2) do not show large changes from Grade 2 to Grade 4 in the relations of comprehension monitoring and knowledge-based inference with listening comprehension tasks; however, the relations of comprehension monitoring and inference to listening comprehension became minimal after accounting for other skills in Figure 3.

Also interesting are the findings about vocabulary and grammatical knowledge—the indirect effect of vocabulary on reading comprehension increased by .17 from Grade 2 to Grade 4 (.21 vs. .38) whereas the opposite pattern was found for grammatical knowledge (.41 vs. .28). The increased indirect effect of vocabulary on reading comprehension appears to be because of the increased direct effect of vocabulary on listening comprehension (from .17 to .33; see Figure 3). This appears to be primarily because of text characteristics (expository texts specifically), as the correlation between vocabulary and expository text comprehension increased from .36 to .51 between Grades 2 and 4 whereas the correlations between vocabulary and the other listening comprehension tasks changed little between grades (.42 to .44 for the TNL task and .46 to .45 for the OWLS task; see Table 2). A review of the expository texts confirmed this speculation as the texts in Grade 4 included advanced vocabulary words such as *environments*, *structure*, *adaptation*, *strands*, and *fabric*. Thus, it appears that increased vocabulary demands in the expository texts of listening comprehension in Grade 4 increased the indirect effect of vocabulary on reading comprehension in Grade 4. An explanation for the decreased indirect effect of grammatical knowledge on reading comprehension from Grade 2 to Grade 4 is unclear, but Table 2 and Figure 3 suggest development as a potential factor: As children develop their grammatical knowledge, grammatical knowledge (at least the knowledge measured in the CASL grammaticality task) may not have captured grammatical demands in comprehension in Grade 4. It is possible that a task that captures more sophisticated grammatical knowledge (e.g., complex sentences with embedded clauses using relative pronouns) may capture grammatical and syntactic demands more adequately in texts in upper grades as texts in upper grades tend to include more syntactically complex sentences (Bailey, 2007; Schleppegrell, 2001).

Finally, the indirect contributions of working memory and attention to reading comprehension showed a different pattern such that the effect increased between grades for working memory (from .29 to .39) whereas it remained similar between grades for attention (.43 in Grade 2 and .41 in Grade 4). The increased indirect effect of working memory on reading comprehension appears to have been driven by its increased indirect effect on listening comprehension (from .21 in Grade 2 to .30 in Grade 4; see Table 5) via multiple pathways: Working memory is related to vocabulary, which had an increased effect on listening comprehension in Grade 4, and working memory was also directly related to theory of mind in Grade 4. Attention did not show such a pattern of increased effect between grades. Although the direct relation of attention to word reading appears to be stronger in Grade 4 (.38) compared with Grade 2 (.27), it did not translate to a larger overall indirect effect on reading comprehension because of the reduced magnitude of the relation of word reading to reading comprehension in Grade 4.

In summary, the present findings suggest a complex picture about the dynamic relations hypothesis. The relative roles of language and cognitive skills on reading comprehension in Grade 2 versus Grade 4 differed across language and cognitive skills, and what is driving the changes appears to be different. The indirect effects of perspective taking (as measured by theory of mind), vocabulary, and working memory on reading comprehension increased in Grade 4 from Grade 2. The increased relative role of theory of mind in Grade 4 appears to have been driven by development whereas the increased role of vocabulary in Grade 4 appears to have been driven by text demands. The stronger relation of working memory in Grade 4 appears to be because of the increased role of vocabulary and theory of mind in the later grade. A different pattern was observed for comprehension monitoring, knowledge-based inference, grammatical knowledge, and attention. In particular, the relations of comprehension monitoring and grammatical knowledge to reading comprehension were weaker in Grade 4 than in Grade 2. The reduced contribution of comprehension monitoring appears to be because of the increased role of theory of mind in Grade 4 and the largely shared covariance between theory of mind and comprehension monitoring.

Limitations, Future Directions, and Conclusion

Findings of the present study should be interpreted with the following limitations in mind. First, as noted above, examining DIER in its entirety was beyond the scope of the present study in terms of component skills and the nature of relations. Although the component skills included in the present study were relatively comprehensive, other skills such as socioemotion, background knowledge, text reading fluency, as well as component skills of word reading (e.g., phonological awareness, orthographic awareness [including letter sound knowledge], and morphological awareness) were not included in the present study. Future studies are warranted. Second, the word reading skill construct in the present study was measured by word reading efficiency tasks rather than a combination of accuracy and efficiency measures. Given that reading skills develop from accuracy to efficiency (Ehri, 2002), and that the children in the present study were not novice readers (i.e., Grades 2 and 4), efficiency measures would likely have captured children's word reading skill sufficiently, but a future replication is needed. Third, we examined listening comprehension as a single latent skill using various tasks and genres (i.e., narrative and expository; also see reading comprehension assessment literature) because theoretically, comprehension of texts in different genres would draw on highly similar processes (e.g., Kintsch, 1988). DIER hypothesizes that the extent to which different component skills contribute to comprehension is likely to vary as a function of text characteristics, which include genre. For example, theory of mind may have a stronger relation to comprehension of narrative texts than expository texts because narrative texts typically include situations requiring greater understanding of others' perspectives (e.g., authors' or characters' thoughts, beliefs, desires, and emotions). Explaining the genre effect is beyond the scope of the present study although the present study does suggest such a trend albeit only in Grade 4 (see the somewhat stronger correlation of theory of mind to the TNL task compared with the expository comprehension task in Table 2). This does not mean, however, that theory of mind would be only relevant to comprehension of narrative texts. Theory of mind is largely a reasoning skill, which is relevant to all types of texts, including expository texts (see Table 2 again for supporting evidence).

Fourth, because of the constraints associated with working in schools and resources, several constructs were measured with single tasks, which entails measurement error and associated issues (e.g., over- or underestimation of path coefficients; see Cole & Preacher, 2014). It would have been ideal to measure all the constructs with latent variables, and future replications are necessary (see covariance matrix in the online supplemental material). One example that would benefit from measurement with multiple tasks includes the construct of attentional control. Attentional control in DIER includes both cognitive or inhibitory control and behavioral control (Kim, 2019). SWAN used in the present study largely measured behavioral attentional control, not cognitive or inhibitory control. Although attentional control as measured by teacher's ratings in the present study has been shown to predict student reading skills (e.g., Little, Hart, Schatschneider, & Taylor, 2016; Sáez, Folsom, Al Otaiba, & Schatschneider, 2012), teachers' ratings of students' attentional control may be confounded with their ratings of students' academic performance. On the other hand, the relation of direct cognitive measures of attentional control to the language and cognitive component skills is mixed (Arrington, Kulesz, Francis, Fletcher, & Barnes, 2014; Christopher et al., 2012; Kim & Phillips, 2014; Locascio, Mahone, Eason, & Cutting, 2010). Future studies wherein attentional control is measured using multiple tasks and approaches (i.e., direct cognitive measures as well as behavioral ratings) would be useful.

Finally, the present study suggested a complex picture about the dynamic relations hypothesis, and future studies are needed to further examine this hypothesis. For instance, provided no floor or ceiling effects, using the same comprehension passages in different grades would help tease out the influence of development from the influence of text characteristics. A series of experimental studies can also manipulate text characteristics (i.e., vocabulary, syntactic, and working memory demands; e.g., Friedman & Miyake, 2000) and examine the relations of component skills to comprehension as a function of text characteristics. Furthermore, child and text features can be examined simultaneously to reveal the interaction of child characteristics and text features for reading comprehension (e.g., Francis et al., 2018) as well as for word reading (e.g., Goodwin et al., 2014; Kearns, 2015).

In this study, we examined the hierarchical relations hypothesis and the dynamic relations hypothesis of DIER as an effort to integrate evidence from multiple lines of work and build a coherent picture about reading development. Future work (including longitudinal as well as experimental studies) is necessary to further investigate and refine DIER.

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