RELATIONSHIP OF INFERENCE-MAKING TO READING COMPREHENSION IN STRUGGLING MIDDLE SCHOOLERS

by

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CHAPTER I

Introduction

Reading comprehension is an essential lifelong skill that becomes fundamental to academic achievement and college and career readiness as students transition from elementary to middle school (Cain & Oakhill, 2006). However, only 31% of 8th grade students in the United States scored at or above proficient status on the most recent 2022 NAEP reading assessment (National Center for Education Statistics, 2022).

Reading comprehension is an active, strategic, and complex process that draws on a reader's skills, knowledge, and cognitive abilities (RAND Reading Study Group, 2002; Cain, Oakhill, & Lemmon, 2004). Students who have difficulties with reading often demonstrate weaknesses in one or more of these capacities (Cain & Oakhill, 2006). Perfetti and Safura's (2014) Reading Systems Framework recognizes key elements that support reading comprehension. The first key element is knowledge sources, including linguistic knowledge, orthographic knowledge, and general knowledge (Perfetti & Safura, 2014). The second key element represents cognitive and language processes involved in reading- decoding, word identification, meaning retrieval, constituent building (sentence parsing), inferencing, and comprehension monitoring (Perfetti & Safura, 2014). These processes interact with each other and with knowledge, in controlled (i.e., not all processes pull from all knowledge sources) and cooperative (i.e., some processes pull from several knowledge sources) ways (Perfetti & Safura, 2014). These processes take place within a limited-resource system (i.e., constraints related to

attention, working memory, and other executive functions; also see Sesma et al., 2009; Spencer et al., 2020).

Relationship Between Inference-Making and Reading Comprehension

The Reading Systems Framework (Perfetti & Safura, 2014) and other models of reading comprehension are important for understanding individual differences in reading comprehension and may help to narrow potential targets for suitable interventions (Barnes et al., 2015). Inference-making, or the ability to infer information that is not explicitly stated in the text, is a critical piece of reading comprehension as reflected in several models of reading, including component skills models, such as the Direct and Inferential Mediation (DIME) framework (Cromley & Azevedo, 2007), and cognitive process models, such as the Construction-Integration model (Kintsch, 1988) and the Landscape Model (van den Broek, Rapp, & Kendeou, 2005).

Empirical studies provide evidence for the importance of inference-making to reading comprehension. Longitudinal studies show that students' ability to make inferences is a predictor of future success in understanding texts (Oakhill & Cain, 2012; Kendeou et al., 2008; Cain, Oakhill, & Bryant, 2004), and inference-making makes significant contributions to reading comprehension, particularly in secondary school readers (Ahmed et al., 2016). Less skilled readers tend to make fewer inferences spontaneously during reading (Hanon & Daneman, 1998; Long, Oppy & Seely, 1994), including adolescent readers who are the focus of the current study (e.g., Barnes et al., 2015; Barth et al., 2015; Denton et al., 2015). Also of relevance to the current study, is the Ahmed et al. (2016) evaluation of the DIME model of reading comprehension in a large group of secondary school students. This components skills model is comprised of

background knowledge, vocabulary, word reading, reading strategies, inference-making, and reading comprehension. The authors found inference-making to be the strongest direct predictor of reading comprehension followed by verbal knowledge (vocabulary and background knowledge). Indirect effects of knowledge and vocabulary through inference making were also found (Ahmed et al., 2016).

Overall, both cognitive process models and component skill models of reading comprehension identify inference-making to be a critical component of reading comprehension (Ahmed et al., 2016; Kintsch, 1988; van den Broek, Rapp, & Kendeou, 2005). As reviewed above, there is also considerable empirical support for the importance of inference-making for reading comprehension.

Types of Inferences

Researchers have suggested several inference taxonomies (e.g. Kintsch, 1993; Warren et al., 1979). Many have found it beneficial to discriminate between text-based inferences, when a reader establishes appropriate, meaningful connections between separate pieces of information literally stated in the text (Hall & Barnes, 2017), and knowledge-based inferences, when a reader establishes appropriate, meaningful connections between information stated in the text and the reader's background knowledge (Hall & Barnes, 2017; Cain & Oakhill, 1999; Kispal, 2008; Hall, 2016).

In the construction-integration model, a text can be represented at three levels: the surface representation, the textbase representation, and the situation model representation (Kintsch, 1988). Surface representation consists of the text's words and syntax. The textbase representation is a network of connected propositions (ideas) named the textbase. The situation model representation consists of a deeper mental representation of

the real-world situation described by the text, which is constructed by integrating information from long-term memory as the text is being read. Although not clear cut, we consider text-based inferences to be relatively more important for building accurate text-based representation, while knowledge-based inferences are relatively more important for constructing the situation model (McNamara & Magliano, 2009).

Although inference-making is critical for reading comprehension, understanding of literal text is also important, particularly for the construction of the text-based representation. Literal questions assess a student's retrieval of information explicitly stated in a text. Less skilled readers find literal questions easier to answer than inferential questions (Basaraba et al., 2012; Barnes et al., 1996; Crais & Chapman, 1987, McCormick, 1992). Most standardized measures of reading comprehension include both literal and inferential questions; however, literal and inferential questions are typically not identified as such nor are they coded separately (e.g., Kulesz et al., 2016). One test that does provide scores for literal and inferential comprehension is the Wechsler Individual Achievement Test or WIAT (Wechsler, 2009); however, the WIAT does not distinguish between text-based and knowledge-based inferences. Similarly, even researcher-created measures of inference-making tend to measure only one type of inference (Elleman, 2017).

One recently developed instrument that was designed to test an intervention that provides instruction in text-based and knowledge-based inferences, the Connect-It Inferential Reading Comprehension Assessment (CIRCA; Clemens & Barnes, 2018) does assess several different types of inference, including three types of text-based inferences - inferences related to pronoun reference, text-connecting inferences between words,

phrases, and sentences in the text, and inferences involving the use of context to derive word meaning – and knowledge-based inferences.

Text-connecting inferences are when a reader establishes appropriate, meaningful connections between separate pieces of information stated in the text. For example, in the sentence, "While Cathy was riding her bike in the park, dark clouds began to gather, and it started to storm" (Hall & Barnes, 2017, p. 280). The reader must associate words such as "clouds" and "storm" to make a connection that the dark clouds caused the storm. The distance between pieces of information to be integrated in a text increases the difficulty of making text-based inferences (Cain, Oakhill & Lemmon, 2004). Cain and Oakhill (1999) determined that less-skilled 7- and 8-year-old comprehenders generated text-connecting inferences at the same ability as the more-skilled comprehenders when they were able to look back at the text. Additionally, it was found that less-skilled elementary-aged comprehenders answered questions demanding a text-connecting inference at a level comparable to their peers (Bowyer-Crane & Snowling, 2005). Not much is known about middle school readers' ability to make text-connecting inferences.

Another type of text-based inference - pronoun reference inferences - connect a pronoun with the person or thing to which it refers (Hall & Barnes, 2017). Readers may be required to connect a noun or noun phrase with the word or phrase to which it refers within single sentences, between adjacent sentences, or often across larger chunks of text. For example, in the sentence "Natalie called Mary's cell phone all day, but she never answered the phone", the reader must infer that the "she" refers to Mary. Less skilled readers have difficulty comprehending a text when it is necessary to draw an inference about a pronouns' reference (Wykes, 1981), particularly when complex processing (i.e,

absence of gender cues, greater working memory load) is required (Oakhill & Yuill, 1986).

Inferring word meanings from context is another type of text-based inference in which readers must infer word meanings from surrounding text (Hall & Barnes, 2017). For example, in the sentence "Cold rain fell all day, making it a dismal Saturday evening," the reader may infer that "dismal" means dreary or gloomy. Children with weaker reading comprehension skills are consistently poorer at inferring the meanings of novel vocabulary items from context and the probability of learning new words from context differs between more skilled and less skilled readers (Cain, Oakhill, & Lemmon, 2004; Barnes et al., 2021). This is particularly true when processing demands (i.e., distance between pieces of information to be integrated) of the task are high (Cain, Oakhill, & Lemmon, 2004).

The CIRCA (Clemens & Barnes, 2018) also measures knowledge-based inferences. Knowledge-based, or gap-filling, inferences are when a reader establishes appropriate, meaningful connections between information literally stated in the text and the reader's background knowledge (Hall & Barnes, 2017). They draw on what the reader knows about the physical and social world to make causal inferences, spatial inferences, temporal inferences, and inferences about intentions, motivations, emotions, and/or traits (Hall & Barnes, 2017), all of which are considered to be important for constructing the situation model (Zwaan, 2016). Research has shown that students with poor comprehension sometimes do not make knowledge-based inferences because they fail to activate the relevant knowledge or do not know when to use that relevant knowledge (Cain & Oakhill, 1999; Elbro, 2018), even when they have the knowledge to make these

types of inferences (Barnes et al., 2015). Students who struggle with reading comprehension have difficulty making knowledge-based inferences regardless of whether the text is in front of them (Cain & Oakhill, 1999). Evidence suggests that struggling readers may have more difficulty with knowledge-based inferences than text-based inferences (Cain & Oakhill, 1999, Bowyer-Crane & Snowling, 2005), and performance on both text-based and knowledge-based inferences predicts comprehension even when the ability to answer literal questions, vocabulary, and word reading ability are controlled (Cain & Oakhill, 1999).

In addition to the individual differences in inference-making that have been found for skilled versus less skilled readers, other potential sources of individual differences have not been well-explored. For example, although gender differences in reading comprehension have been well-documented (e.g., Logan & Johnston, 2009), often showing advantages for girls over boys (Chiu & McBride-Chang, 2006; Lietz, 2006), little is known about whether sex differences exist for inference making. Given the importance of inference-making to reading comprehension, are there gender differences in inference-making? One study found that females generated more reinstatement inferences, a type of text-based inference that connects the currently read sentence with information from sentences that happened earlier in the text (Clinton et al., 2014). No other gender differences in text-based or knowledge-based inference-making were found (Clinton et al., 2014). Finally, even though it is well known that inference making shows developmental differences between younger and older children (Barnes et al., 1996), little is known about whether there are developmental changes in inference-making in the middle school grades.

Despite evidence that inference generation makes an important contribution to reading comprehension (e.g., Ahmed et al., 2016; Oakhill & Cain, 2012), no studies to our knowledge have investigated how well different types of inferences (text-connecting, pronoun reference, word meaning from context, knowledge-based) predict overall reading comprehension, as well as literal and inferential reading comprehension, for students in middle school with below-average reading comprehension, and whether these findings are similar across the middle school grades and in males and females.

Purpose of the Study

The purpose of this study was to evaluate how well different types of text-based inferences (text-connecting, pronoun reference, word meaning from context) and knowledge-based inferences measured by the CIRCA (Clemens & Barnes, 2018) predict reading comprehension achievement for less-skilled middle school readers in grades 6, 7, and 8. We used the Wechsler Individual Achievement Test 3rd ed. (WIAT-III) to measure reading comprehension achievement (Wechsler, 2009). The WIAT-III allowed us to look at literal and inferential comprehension separately (Wechsler, 2009). Pretest data from a randomized control trial (Barnes et al., 2020) was utilized to investigate the following research questions:

1. Do text-based (pronoun reference, text-connecting, word meaning from context) and knowledge-based inferences predict reading comprehension achievement over and above word reading efficiency, age, and gender?
2. Do text-based and knowledge-based inferences predict literal and inferential text comprehension over and above word reading efficiency, age, and gender?

3. Do knowledge-based inferences uniquely predict variability in reading comprehension achievement and in literal and inferential text comprehension after accounting for word reading efficiency, age, gender, and text-based inference-making?
4. Are there age and sex-related effects on inference-making?

Based on the review of the literature, we hypothesized that all four inference types measured in the CIRCA will predict reading comprehension after controlling for word reading, age, and gender. We hypothesized that text-based (i.e., text-connecting, word meaning from context, and pronoun reference inferences) would be more important for predicting literal vs. inferential reading comprehension because these types of inferences are thought to be important for constructing the text-based representation. We also hypothesized that knowledge-based inferences would predict variability in inferential text comprehension over and above word reading efficiency, age, gender, and text-connecting inferences because these types of inferences are important for constructing the situation model described by the text. We did not make directional hypotheses for sex- or age-related effects on inference making given the lack of evidence in the literature from which to make predictions.

CHAPTER 2

Method

This study used data from the pretest assessment from a randomized control trial (Barnes et al., 2020) that examined the efficacy of an inferential reading comprehension intervention for middle school students. The sample completed pre-test measures which were used to examine the research questions.

Participants

Participants were nominated from three middle schools in three different school districts in one state in the southwestern United States. The middle schools served grades 6, 7, and 8. The participants were nominated by school administrators. The students nominated had low performance on the state accountability English Language Arts exam in the previous school year. IRB- approved consent forms were distributed to all identified students. Students whose parents provided informed consent and students who assented to participate were assessed. One hundred and fifty-five students were assessed at pre-test.

75.3% of school one, 81.8% of school two, and 78.5% of school three, were categorized as economically disadvantaged in the year in which the study was conducted (fall and spring semesters of the 2018-2019 school year). The one hundred and fifty-five participants are described in Table 1 (see page 11). The majority were female (54.84%) and White (72.26%). Furthermore, 6.45% of the students were receiving special education services and 12.48% were English learners.

Table 1
Participant Demographics

	N	%
Gender		
Female	85	54.84
Male	70	45.16
Grade Level		
6th	50	32.26
7th	44	28.39
8th	61	39.35
Ethnicity		
Hispanic	95	61.29
Non- Hispanic	60	38.7
Race		
White	112	72.26
African American	36	23.23
American Indian	5	3.23
Other	2	1.29
Special Education		
Yes	10	6.45
No	145	93.55
IEP		
Yes	30	19.35
No	125	80.65
English Learner		
Yes	24	12.48
No	131	84.52

Measures

The assessment battery included measures of word reading fluency, inferential reading comprehension, and general reading comprehension, including literal and inferential components.

Test of Word Reading Efficiency 2nd ed., Sight Word Efficiency. The Sight Words Efficiency (SWE) is a subtest of the Test of Word Reading Efficiency 2nd ed.

(TOWRE-2; Torgesen et al., 2012). It was used to assess students' word reading skills and fluency. Students are timed for 45 seconds to read from a list of words that increases in difficulty. The score is the number of words read aloud correctly in 45 seconds. The TOWRE-2 manual reports reliability ranges of between .90 and .99. The standard scores, based on age, were used in analyses.

Connect-It Inferential Reading Comprehension Assessment. The Connect-It Inferential Reading Comprehension Assessment (CIRCA; Clemens & Barnes, 2018) was used to assess inferential reading comprehension. The CIRCA is a 42-item test aligned with inference making skills (i.e., pronoun reference, text-connecting inferences, word meaning from context, knowledge-based inferences) that students read silently on an untimed basis. The CIRCA is group-administered and takes participants about 30 minutes to complete. The items are sectioned, which aligns with the four types of inferences (text-connecting, pronoun reference, word meaning from context, knowledge based), and sections vary in response formats and reading demands. The larger parent study (Barnes et al., 2020) assessed the reliability and validity of the CIRCA. Correlations between the CIRCA and concurrent administration of the Reading Comprehension subtest of the Wechsler Individual Achievement Test was 0.68 (Clemens & Barnes, 2018). Internal consistency (coefficient alpha) for the full measure (all 42 items) at pre- and posttest were .88 and .89, respectively. Proportion correct scores for each inference type were used in analyses.

Wechsler Individual Achievement Test 3rd ed., Reading Comprehension. The Reading Comprehension subtest of the Wechsler Individual Achievement Test 3rd ed. (WIAT-III; Wechsler, 2009) was used to assess reading comprehension. Students silently

read passages and verbally answer open-ended literal and inferential questions asked by the examiner. The passages were expository and narrative. The authors reported an average test-retest reliability estimate of 0.83 for students in middle school for the Reading Comprehension subtest (Wechsler, 2009). Scaled scores as well as separate proportion correct scores for literal and inferential questions, as coded in the WIAT manual, were used in analyses.

CHAPTER 3

Results

Table 2 shows the mean, standard deviation, and minimum, and maximum scores associated with each variable. The correlations amongst the predictors included in the study were examined and presented in Table 3. As seen in Table 3 (see page 15), reading comprehension correlated weakly to moderately with all other variables. This indicates that further analyses of the relationships among these variables were warranted.

Table 2

Descriptive variables for measures (n=155)

Measure		M (SD)	Min-Max
WIAT-III (SS)		87 (7.93)	62-116
	Literal (PC)	66 (21)	0-100
	Inferential (PC)	43 (14)	7-87
TOWRE- 2 (SS)		91.3 (10.8)	64-127
CIRCA		27.6 (7.94)	9-42
	Pronoun Reference (PC)	67 (26)	0-100
	Word-Meaning (PC)	62 (23)	0-100
	Text-Connecting (PC)	70 (17)	27-100
	Knowledge-Based (PC)	63 (26)	0-100

Note: WIAT-III = Wechsler Individual Achievement Test-Third Edition; SS = standard score; PC = proportion correct; TOWRE-2 = Test of Word Reading Efficiency- Second Edition; CIRCA = Connect-IT Reading Comprehension Assessment

To explore the degree to which inference making predicted reading comprehension over and above word reading skills, age, and gender, we performed a series of hierarchal multiple regression analyses. In these analyses, we entered word reading skills, as measured by the TOWRE-2 SWE (Torgesen et al., 2012), age, and gender at step 1. Word reading is thought to be an essential prerequisite of reading comprehension, so therefore logically, contributions of other skills should be examined

Table 3

Intercorrelations Between Variables

Variable	1	2	3	4	5	6	7
1. Age	--						
2. Word Reading	0.009	--					
3. Reading comprehension	-.227**	.321**	--				
4. Pronoun reference	0.118	.262**	.385**	--			
5. Text-Connecting	0.002	.331**	.428**	.477**	--		
6. Word Meaning	0.085	.350**	.424**	.562**	.646**	--	
7. Knowledge-Based	0.058	.346**	.464**	.479**	.552**	.600**	--

Note. ** = Correlation is significant at the 0.01 level (2-tailed); Reading comprehension= WIAT-III (Standard Score); Pronoun reference, text-connecting, word meaning, knowledge-based= CIRCA (Proportion Correct)

after person level variable (word reading, gender, age) are taken into account (Oakhill & Yuill, 1996). We also controlled for age given the grade range for participants in the study. Text-based inferences (pronoun reference, word meaning from context, and text-connecting), as measured by the CIRCA (Clemens & Barnes, 2018) were entered at step 2. Because we assumed text-based inferences are important for building an accurate text-based representation, we put those inferences in the model in step 2. In step 3, knowledge-based inferences were entered, as measured by the CIRCA (Clemens & Barnes, 2018). This was done to explore the degree to which each broad type of inference as well as specific inference types predict reading comprehension at the middle school level. The dependent variables were reading comprehension achievement (standard scores), literal reading comprehension (proportion correct scores) and inferential comprehension (proportion correct scores), as measured by the WIAT-III (Wechsler,

2009). Different models (steps in the regressions) were used to address specific research questions.

Reading Comprehension Achievement

Hierarchical multiple regression was performed to investigate the extent to which inference type (pronoun reference, text- connecting, word meaning from context, and knowledge-based) predicted reading comprehension after statistically controlling for word reading, age, and gender.

Reading comprehension achievement was entered as the dependent variable, as measured by the WIAT-III standard score. Table 4 summarizes findings from the models obtained at each step. In the first step, three predictors were entered: word reading, age, and gender. This model was statistically significant $F(3, 147) = 9.79$; $p < .001$ and explained 15 % of variance in reading comprehension scores. Age and word reading ability were significantly related to standardized reading comprehension scores ($\beta = -.24$ $p < .01$; $\beta = .33$, $p < .001$, respectively).

Table 4

Summary of Hierarchical Regression Analysis for Inferencing Variables Predicting WIAT-III Reading Comprehension (Standard Scores) with Age, Gender, and Word Reading Statistically Controlled

Analysis		Final βs							Summary statistics with reading comprehension as dependent variable				
Model	Independent variables	A	G	WR	PRI	TCI	WMI	KBI	R	Adj R^2	ΔR^2	ΔF	d*fs*
1	A + G + WR	-0.24**	-0.00	0.33***	-	-	-	-	0.41	0.15	0.17	9.79	3, 147
2	A + G + WR + PRI + TCI + WMI	-0.27***	0.08	0.17*	0.19*	0.18	0.19	-	0.59	0.32	0.18	13.27	3, 144
3	A + G + WR + PRI + TCI + WMI + KBI	-0.27***	0.09	0.14*	0.15	0.12	0.11	0.25***	0.62	0.35	0.03	7.80	1, 143

Note. A = age; G = gender; WR = word reading; PRI = pronoun reference inference; TCI = text- connecting inference; WMI = word meaning from context inference; KBI = knowledge- based inference; Adj= Adjusted.

*p<.05. ** p <.01. *** p< .001.

The second step added text-based inferences (pronoun reference, text-connecting, word meaning from context) into the model. The R^2 change was significant ($\Delta R^2 = .17$, $p < .001$) and the model explained 32% of the variance. In Model 2, age, word reading, and

pronoun reference were statistically significant (β = -.27, p < .001; β = .17, p < .05; β = .19, p < .05, respectively).

The introduction of knowledge-based inferences in Step 3 explained an additional significant 3.4% of variance in reading comprehension scores (ΔR^2 = .034; F (1, 143) = 7.80; p < .01). Altogether, the independent variables accounted for 35% of the variance in reading comprehension. The third model indicated that age, word reading, and knowledge-based inferences were significantly associated with reading comprehension (β = -.27, p < .001; β = .14, p < .05; β = .25, p < .01 respectively).

Literal Reading Comprehension

We conducted a second hierarchical regression analysis to investigate the ability of inference type (pronoun reference, text-connecting, word meaning from context, and knowledge-based) to predict levels of literal reading comprehension after statistically controlling for word reading, age, and gender. Proportion correct for literal comprehension questions on the WIAT-III was entered as the dependent variable. The statistical output contained 3 models, summarized in Table 5.

Table 5

Summary of Hierarchical Regression Analysis for Inferencing Variables Predicting WIAT-III Literal Reading Comprehension (Proportion Correct) with Age, Gender, and Word Reading Statistically Controlled

Analysis		Final βs							Summary statistics with reading comprehension as dependent variable				
Model	Independent variables	A	G	WR	PRI	TCI	WMI	KBI	R	Adj R^2	ΔR^2	ΔF	d*fs*
1	A + G + WR	-0.15	-0.04	0.27**	-	-	-	-	0.31	0.08	0.10	5.37	3, 147
2	A + G + WR + PRI + TCI + WMI	-0.20**	0.02	0.13	0.30**	-0.03	0.23*	-	0.52	0.24	0.17	11.52	3, 144
3	A + G + WR + PRI + TCI + WMI + KBI	-0.21**	0.02	0.11	0.27**	-0.08	0.17	0.20*	0.54	0.26	0.02	4.39	3, 143

Note. A = age; G = gender; WR = word reading; PRI = pronoun reference inference; TCI = text- connecting inference; WMI = word meaning from context inference; KBI = knowledge- based inference; Adj= Adjusted.

*p<.05. ** p <.01. *** p< .001.

In the first step of the hierarchical multiple regression, three predictors were entered: word reading, age, and gender. This model was statistically significant F (3, 147) = 5.37; $p < .01$ and explained 8% of variance in literal reading comprehension scores. Only word reading was related to reading comprehension ($\beta = .27$, $p < .001$).

After entry of pronoun reference, text-connecting, and word meaning from context inferences at Step 2, the total variance explained by the model was 24% ($\Delta R^2 = .174$; F (3, 144) = 11.52; $p < .001$). Age, pronoun reference, and word meaning from context inferences were statistically significant ($\beta = -.20$, $p < .01$; $\beta = .30$, $p < .001$; $\beta = .23$, $p < .05$ respectively).

The introduction of knowledge-based inferences in Step 3 explained an additional 2.2% of variance in literal reading comprehension scores ($\Delta R^2 = .022$; F (1, 143) = 4.39; $p < .05$). The third model, with the addition of knowledge-based inferences, indicated that age, pronoun reference, and knowledge-based inferences were significantly associated with literal reading comprehension ($\beta = -.21$, $p < .01$; $\beta = .27$, $p < .01$; $\beta = .20$, $p < .05$ respectively). Final adjusted $R^2 = .260$ ($p < .001$) in Model 3 for literal reading comprehension.

Inferential Reading Comprehension

Hierarchical regression analysis was conducted to investigate the ability of inference type to predict levels of inferential reading comprehension after statistically controlling for word reading, age, and gender. Proportion correct of inferential comprehension questions on the WIAT-III was entered as the dependent variable. The statistical output contained 3 models, summarized in Table 6 (see page 19).

Table 6

Summary of Hierarchical Regression Analysis for Inferencing Variables Predicting WIAT-III Inferential Reading Comprehension (Proportion Correct) with Age, Gender, and Word Reading Statistically Controlled

Analysis		Final βs							Summary statistics with reading comprehension as dependent variable				
Model	Independent variables	A	G	WR	PRI	TCI	WMI	KBI	R	Adj R^2	ΔR^2	ΔF	d*fs*
1	A + G + WR	-0.10	0.03	0.32***	-	-	-	-	0.336	0.10	0.11	6.23	3, 147
2	A + G + WR + PRI + TCI + WMI	-0.12	0.12	0.16*	0.12	0.20*	0.22*	-	0.539	0.26	0.18	11.99	3, 144
3	A + G + WR + PRI + TCI + WMI + KBI	-0.12	0.12	0.14	0.09	0.16	0.16	0.20*	0.56	0.28	0.02	4.76	1, 143

Note. A = age; G = gender; WR = word reading; PRI = pronoun reference inference; TCI = text- connecting inference; WMI = word meaning from context inference; KBI = knowledge- based inference; Adj= Adjusted.

*p<.05. ** p <.01. *** p< .001.

In the first step of the hierarchical multiple regression, three predictors were entered: word reading, age, and gender. This model was statistically significant F (3, 147) = 6.23; $p < .001$ and explained 10% of variance in inferential reading comprehension scores. Only word reading ability was related to reading comprehension ($\beta = .32$, $p < .001$).

After entry of pronoun reference, text-connecting, and word meaning from context inferences at Step 2, the total variance explained by the model was 26% ($\Delta R^2 = .177$; F (3, 144) = 11.99; $p < .001$). Word reading, text-connecting, and word meaning from context inferences were statistically significant ($\beta = .16$, $p < .05$; $\beta = .20$, $p < .05$; $\beta = .22$, $p < .05$ respectively).

The introduction of knowledge-based inferences in Step 3 explained an additional 2.3% of variance in inferential reading comprehension scores ($\Delta R^2 = .023$; F (1, 143) = 4.76; $p < .001$). Altogether, the independent variables accounted for 28% of the variance in inferential reading comprehension. The third model indicated that only knowledge-based inferences were uniquely significantly associated with inferential reading comprehension ($\beta = .20$, $p < .05$).

CHAPTER 4

Discussion

In the present study, we tested whether two types of inferences - text-based and knowledge-based - predicted struggling middle school readers' reading comprehension achievement as measured by the WIAT-III. Second, because text-based inferences are implicated as necessary for constructing text-based representations and knowledge-based inferences are implicated as necessary for constructing the situation model, we tested the extent to which text-based and knowledge-based inferences differentially predicted literal and inferential reading comprehension. We expected that both types of inference making would significantly contribute to struggling middle school readers' comprehension over and above word reading ability and age. We also hypothesized that the three types of text-based inferences would be more important for predicting literal reading comprehension and that knowledge-based inferences would predict variability in inferential text comprehension over and above word reading efficiency, age, and text-based inferences. In addition, we asked whether there were age- and gender-related effects on literal and inferential reading comprehension outcomes.

Consistent with our predictions, the findings indicated that text-based inferences predicted reading comprehension achievement, and both literal and inferential text comprehension. Step 2 of all models revealed significant, additional variance explained by text-based inferences that ranged from 17% to 18%. Also consistent with our predictions, knowledge-based inferences predicted significant unique variance in standardized reading comprehension and in inferential comprehension outcomes (Step 3

of models showed increases of between 2-3% in terms of variance explained over and above previous steps); however, this was also true for literal text comprehension. Finally, in this group of struggling middle school comprehenders, word reading efficiency accounted for significant unique variance in standardized reading comprehension outcomes with all predictors in the model, and for significant unique variance for all reading comprehension outcomes at Step 1. This is consistent with other studies of older poor comprehenders where word reading efficiency is still important for reading comprehension achievement (Vaughn et al., 2012). Finally, gender was not related to the measure of inferential comprehension. Although Clinton et al. (2014) found one gender-related effect on inference-making in their study, our study used different measures and the participant demographics also differed. Furthermore, we did not test whether there were gender effects for each of the four types of inferences we measured in this study. The findings and their implications are discussed in more detail below.

Reading Comprehension Achievement

Consistent with previous work (e.g., Ahmed et al., 2016; Cain & Oakhill, 1999), both text-based and knowledge-based inference-making predicted reading comprehension achievement over and above word reading fluency. Only pronoun reference provided unique contributions from the text-based inferencing measures; although this unique effect was no longer significant when knowledge-based inferences were added to the model. It is unclear why age is a significant unique predictor of grade-standardized reading comprehension achievement scores with all other predictors in the model. However, it should be noted that the correlation of age and reading comprehension achievement is negative. This means that increasing age is associated with decreasing

reading achievement in this group of struggling middle school readers. Although our study is cross-sectional in terms of age and grade, Vaughn and her colleagues (2012) reported something similar for their business-as-usual control group in their longitudinal intervention study; in that study, students who did not receive intervention had lower standardized reading comprehension scores over the course of the study, while the positive effect of the intervention was to maintain standard score standings for the intervention group. In relation to our study, the age effect may mean that because we used a grade standardized measure of reading comprehension, our older participants needed to answer more questions correct than our younger participants. The age effect may be reflecting that this group of less skilled comprehenders may have had similar skills in reading comprehension, despite their age. This furthers the importance of starting intervention early in middle school to address this gap.

Literal Reading Comprehension

For literal text comprehension we expected text-based inferences to make a significant contribution and we found the only text-based inference that was uniquely predictive was pronoun reference inferences. Furthermore, the findings from the second model that included the three types of text-based inferences indicated that pronoun reference inferences and word meaning from context inferences were uniquely predictive of literal reading comprehension. Even in the final model that included all types of inferences, pronoun reference inferences remained uniquely predictive of literal reading comprehension. The ability to make text locally coherent by connecting pronouns with their referents in a text seems to be important for literal comprehension. Texts typically never contain fully explicit descriptions, which requires readers to make connections

between text and establish coherence in the text-base (Rawson & Kintsch, 2005). Garnham & Oakhill (1985) suggest that no coherent representation of the situation described in a text can be constructed until pronouns are resolved. It has been found that less skilled readers have difficulty comprehending a text when it is necessary to draw an inference about pronouns' reference (Wykes, 1981). Furthermore, less skilled comprehenders are consistently poorer at inferring the meanings of novel vocabulary items from context (Cain, Oakhill, & Lemmon, 2004). Taking this into consideration, less skilled readers may have more difficulty establishing coherence in the text-base.

Although we did not hypothesize that knowledge-based inferences would predict literal text comprehension over and above text-based inferences, knowledge is an important predictor of reading comprehension (Ahmed et al, 2016; Cromley & Azvedo, 2007). The *knowledge-based account* of reading comprehension (Ericsson & Kintsch, 1995) states that readers with deep, high-quality knowledge stores are better able to proficiently use their existing knowledge to comprehend text, and studies have shown that more skilled and less skilled readers differ in how well they use their knowledge to facilitate comprehension (e.g., Cain et al., 2001). Many consider knowledge-based inferences to be important for constructing the situation model (McNamara and Magliano, 2009), which involves connecting ideas in the text to a reader's prior knowledge (Kintsch, 1988). Langer (1985) stated that elementary aged students tended to use a strategy that involved the use of global rather than local knowledge for answering both literal and inferential questions. Knowledge-based inferences predicting literal text comprehension may be the result of more careful use of global knowledge.

Inferential Reading Comprehension

The findings from the second model that included the three types of text-based inferences indicated that text-based inferences appear to also be important for inferential comprehension, not only for literal comprehension, and furthermore, text-connecting inferences, and word meaning from context inferences were uniquely predictive of inferential text comprehension, although these two types of text-based inferences were no longer uniquely predictive after knowledge-based inferences were added to the model. These findings suggest that inferential comprehension, at least as measured by the WIAT-III, draws on both text-based and knowledge-based inferences and that the ability to make pronoun references as well as figure out the meanings of new words from context are related to how well one does on the inferential questions of the WIAT-III. One thing that is important to note here is that the WIAT-III does not further differentiate inference questions into those that require text-based inferences versus those that require knowledge-based inferences. Some of the questions may measure text-connecting inferences, while other questions may measure knowledge-based inferences. If, for example, most of the inferential questions on the WIAT-III required the student to generate a knowledge-based inference, it may make sense that text-connecting inferences were no longer uniquely predictive when knowledge-based inferences were added to the model. However, as stated above, Langer (1985) stated that elementary aged students tended to use a strategy that involved the use of global rather than local knowledge for answering both literal and inferential questions. Knowledge-based inferences predicting inferential text comprehension may also be the result of more careful use of global knowledge. Therefore, these findings for inferential comprehension may need to be

interpreted with caution due to the overlap of these inference types measured in the inferential questions in the WIAT-III that perhaps muddles any comparisons of specific inference generation. Further research may be needed to distinguish between the inferential questions that require text-based inferences and those that require knowledge-based inferences.

In summary, the findings indicate that text-based inferences and knowledge-based inferences are predictive of general reading achievement as well as for literal and inferential text comprehension. Furthermore, inferences that require the integration of knowledge were uniquely predictive of all types of comprehension measured in this study, even for literal text comprehension. As noted previously, we, as well as others, consider knowledge-based inferences to be important for constructing the situation model (McNamara and Magliano, 2009). Radvansky et al. (2001) stated that the "creation of a situation model is essentially an inference-making process in which the given information and general world knowledge is used to construct an understanding of the described situation" (p. 156). Due to knowledge-based inferences being important for constructing the situation model and the situation model being important to reading comprehension, the finding that knowledge-based inferences uniquely predict reading comprehension was perhaps not unexpected (McNamara and Magliano, 2009; Radvansky et al., 2001). However, it is also important to not lose sight of the fact that inferences that required the integration of information within the text were also critical for all three reading comprehension outcomes and accounted for a considerable amount of variance on those outcomes.

Limitations

We acknowledge that the present investigation has several limitations. As noted above, the models accounted for up to only 35% of the variance in reading comprehension achievement. This implies that important variables may have been left out of the models even though the goal of the study was not to model reading comprehension outcomes per se. Because vocabulary and world knowledge make both direct and indirect contributions to reading comprehension through inference-making for secondary school students (Ahmed et al., 2016), future research might examine the addition of vocabulary and background knowledge, and their potential interactions with the different types of inference-making studied here.

A second limitation of the study lies in the fact that the sample was not representative of all middle school students. Our sample only included struggling comprehenders. The implications of how different inferences relate to general reading comprehension achievement may be limited due to our sample. An important aim for future studies is to include students with a range of reading skills to see whether the pattern of relationships we found are similar across different levels of reading comprehension achievement.

Additionally, our study included only one standardized measure of reading comprehension, the WIAT-III. Ideally, reading comprehension measures should use varying types of texts and modalities (Cutting & Scarborough, 2006). Different reading comprehension measures may sample different skills and cognitive processes related to reading comprehension (Cutting & Scarborough, 2006). Future studies should include the prediction of performance on different types of reading comprehension measures or on

latent measures of reading comprehension to better understand the relationship of different types of inference making to reading comprehension achievement. However, we do think there is value in also looking at the prediction of literal vs. inferential text comprehension and this is something that most standardized reading comprehension measures are not able to provide.

Implications

Despite these limitations, there are theoretical and practical implications of the findings for struggling middle school readers. This study provides a first step in identifying how different types of inferences predict reading comprehension achievement. The findings support that inference making, both text- based and knowledge-based inference generation, are important for literal and inferential reading comprehension. The findings provide additional empirical support for models of reading comprehension, such as the DIME model (Cromley & Azevedo, 2007; Ahmed et al., 2016), which hypothesize that reading comprehension is affected by interactions between the reader and the text. Understanding what student characteristics influence reading comprehension may lead to the development of more effective interventions to address the academic needs of struggling middle school readers.

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