Reading and Cognitive Correlates Underlying Inferencing Among Adolescent Readers

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Abstract

Little is known about how components of working memory (i.e., passive resonance of information in working memory, limited capacity working memory, and suppression of irrelevant information from working memory) impact near and far inferencing among adolescent readers. Using path analyses, the current study evaluated the relations of near and far inferencing, vocabulary, general knowledge, strategy use, and word reading efficiency as well as components of working memory among 1,085 students in Grades 7-12. Results indicated that near inferencing has the largest direct effect on far inferencing. Further, in a model that also included direct and indirect effects of cognitive processes on far inferences, results suggested that working memory ($\beta = .08$, $p = .02$), suppression ($\beta = .07$, $p = .03$), near inferencing ($\beta = .25$, $p < .001$) and vocabulary ($\beta = .18$, $p < .001$) had significant direct effects on far inferencing; whereas suppression ($\beta = .13$, $p < .001$), passive resonance in memory ($\beta = .12$, $p < .001$), background knowledge ($\beta = .12$, $p = .005$), and vocabulary $\beta = .27$, $p < .001$) had significant direct effects on near inferencing. In sum, results suggest that cognitive processes impact inferencing among adolescents.

Keywords: Near inferencing, far inferencing, adolescents, reading, cognitive correlates

Introduction

Theories of discourse and text comprehension suggest that to understand text, readers must build a coherent mental representation of the situation described by the text (Graesser et al., 1994; Kintsch, 1988; van den Broek et al., 2005). To establish this coherent text representation, readers generate inferences to bridge conceptual gaps between two sections of text, and form more elaborate associations about events they predict may arise as the text unfolds (van den Broek et al., 2005). In terms of inferences that serve to link information within the text, the sources of this information may be close together or farther apart in the text resulting in the making of "near" and "far" inferences, respectively (McKoon & Ratcliff, 1992).

Component Skills Related to Inferencing

Component skills models, such as the Direct and Inferential Mediation Model (DIME; Cromley & Azevdo, 2007) of reading comprehension, hypothesize that a set of basic reading and reading-related skills underlie reading comprehension, such as word recognition, fluency, vocabulary, general knowledge, and discourse processing skills (e.g., inference making and strategic monitoring of text) (Cromley & Azevdo, 2007; Cromley et al., 2008, 2010). The DIME model also explicitly tests the relation of several of these component skills to inferencing itself. Further, it postulates direct and indirect effects of background knowledge, strategies, word reading, and word knowledge on inferencing (Cromley & Azevedo, 2010), which are testable hypotheses about mediation (Baron & Kenny, 1986). Using this approach, Cromley and Azevedo (2007) report that background knowledge (.21), word knowledge (.21), and strategies (.52) have significant direct effects on inferencing after controlling for word reading ability among adolescent readers, with similar findings reported among young adult readers (Cromley et al., 2008, 2010). This body of literature suggests that word and world knowledge, reading strategies, and word reading account for variance in inferencing generally among older readers.

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Process models of comprehension posit that constructing meaning is largely inferential in nature and describe the lower- and higher-level processes involved (Kintsch, 1988; van den Broek et al., 2005). These theoretical accounts are supported by recent work with older readers showing that successful construction of a mental model of text is facilitated by processes that support understanding of words, sentences, and their respective relations (Kendeou, 2015).

Three orders of component skills have consistently been identified as important: foundational skills that translate print into linguistic units, higher-level language skills that construct meaning from those linguistic units, and cognitive skills that control and regulate component processes so that the reader may focus on important ideas in the text (Florit et al., 2011; Kendeou, 2015). With respect to foundational skills (e.g., word and world knowledge and word reading), theory has regularly suggested that the faster words can be translated, the more resources readers have available for meaning making (Perfetti, 1985). With respect to higher-level language skills (e.g., inference making), research has consistently demonstrated that the ability to integrate ideas explicit in the text and ideas in text with relevant background knowledge is essential for comprehension (Kintsch, 1988). Finally, with respect to cognitive skills (e.g., working memory and attentional control), both inference making and reading comprehension require that the reader organize, prioritize, and judge the relevance of information within the limits of working memory to maintain focus on what is important for understanding (Cain, 2006). However, the influence of cognitive skills is impacted by features of the text (Floritt et al., 2011; Kendeou, 2015).

It is unclear whether these skills contribute in the same way to inferences that maintain coherence when all the information needed to generate the inference is close together in the text versus when that information is farther apart. Examining previous validation studies of the DIME model, we see that the inference measures used to assess inferencing among adolescents and adults have tapped a variety of inference skills (e.g., pronominal reference, text-to-text inferences, and knowledge-to-text inferences at the sentence and paragraph level) (Cromely & Azevedo, 2007; Cromley et al., 2008, 2010). However, these studies have not examined whether the direct and indirect effects of foundational skills differ significantly when forming near and far inferences among older readers. Moreover, variability in cognitive processes have been hypothesized as important sources of individual differences in comprehension among adolescents and adult readers (Gernsbacher, 1996; Just & Carpenter, 1992; van den Broek et al., 2005). However, current examinations of the DIME model have not included cognitive processes in their prediction of reading comprehension or inferencing. The present study sought to understand their role in making inferences.

The cognitive processes hypothesized to relate to inferencing among adolescent readers are reviewed in greater detail below.

Memory Resources

Inferencing requires that the reader integrate information across text sections and this process, in turn, requires that the reader remember and connect multiple text elements needed to maintain both local and global coherence (Hua & Keenan, 2014). Therefore, working memory, the capacity to store and manipulate ideas from text (Daneman & Merikle, 1996), is implicated.

Previous studies examining individual differences in working memory and their relations to comprehension report that memory for literal text is strongly related to inferences that maintain coherence (Cain, 2006; Cain et al., 2001; Leather & Henry, 1994; Oakhill et al., 2003), with highly accessible knowledge twice as likely to be integrated with information in text than knowledge that is available but less accessible (Barnes et al., 1996). When memory for text is perfect, differences between skilled and less skilled comprehenders disappear, suggesting that less skilled comprehenders can form inferences as well as skilled comprehenders if they have the relevant information in memory (Hua & Keenan, 2014). Yet, even in instances where readers possess the requisite knowledge to form the inference, less skilled comprehenders execute inferential processes slower than skilled comprehenders (Barnes et al., 2015).

A handful of studies have modeled the relationship between working memory, vocabulary, and inference making among typically developing elementary-grade readers (Chrysochoou et al., 2011; Currie & Cain, 2015; Kim, 2016; Language and Reading Research Consortium [LARRC] et al., 2015). But only two studies have examined whether the effect of working memory varies by inference type. For example, Currie and Cain (2015) report that although working memory is associated with the accurate formation of near and far inferences among typically developing readers ages 6-10 years, the effect is fully mediated by vocabulary. In contrast, Chrysochoou et al. (2011) found that while vocabulary fully mediates the relationship between working memory and near inferences among 9-year-old typically developing Greek children, it only partially mediates the relationship between working memory and far inferences. In short, these studies suggest that (a) the relation of working memory to near and far inferences may change with reading development and (b) the role of working memory may vary by the type of inferences that readers are required to form when reading text (i.e., near vs. far inferences). To date, no study has examined the role of working memory and verbal knowledge in the formation of near and far inferences among students in the secondary grades.

Suppression

The Structure Building Framework (Gernsbacher, 1996) posits a central role for suppression of irrelevant information in reading comprehension. Specifically, Gernsbacher (1996) suggests that as text is being processed, two complementary mechanisms (i.e., enhancement and suppression) help to build a coherent structure of the text called a situation model (Kintsch, 1988). The situation model is the reader's mental model of the text. It includes ideas explicitly stated in the text, inferences generated to understand ideas implied by the text, as well as the reader's knowledge of the topic and their beliefs about the world.

The situation model is actively updated as the reader processes text through enhancement and suppression. First, ideas that cohere, strongly relate, or easily connect with the evolving situation model of text are activated or enhanced to promote their integration into the model (i.e., enhancement). Second, ideas that are weakly associated, irrelevant, or less coherent are suppressed or dampened to prevent their integration into the evolving situation model of the text (i.e., suppression). In short, enhancement and suppression determines which information from text or general knowledge should be maintained in active memory to support comprehension and which information should be eliminated because it is no longer essential for understanding.

In the Structure Building Framework, less efficient suppression mechanisms jeopardize comprehension because weakly associated information may be integrated into the evolving mental model of text thereby limiting understanding (Cain, 2006; Gernsbacher, 1997; Nation et al., 1999; Pimperton & Nation, 2010). Supporting this framework are several studies wherein significant differences on assessments measuring suppression have been reported for skilled and less skilled comprehenders matched for word reading ability as well as in other studies that matched for nonverbal cognitive ability (Barnes et al., 2004; Borella et al., 2010; Caretti et al., 2005; Gernsbacher & Faust, 1991; Pimperton & Nationl, 2010). However, more recent work by Barnes et al. (2015) reports that after accounting for word reading efficiency and nonverbal IQ, suppression uniquely accounted for less than 1% of the variance in reading comprehension among students in the secondary grades. Further, their comparison of suppression in less skilled comprehenders matched to adequate comprehenders in the secondary grades, on age, word reading efficiency, and nonverbal IQ, failed to replicate findings from previous studies of elementary-grade readers.

To date, only one study has directly tested this hypothesis in the context of inference making. Specifically, Pike et al. (2010) examined whether distracting illustrations facilitate the making of inferences across larger text distances by reducing the processing load in working memory. In their study, students in Grades 2-6 read short stories that were followed by either a "consistent" illustration (i.e., illustration highlights the information that must remain activated to form the correct inference), "inconsistent" illustration (i.e., illustration highlights the information that must be ignored to form the inference), or "text only" (i.e., text with no accompanying illustration) and then answered inference questions.

Results revealed that illustrations highlighting relevant information to hold activated in memory had a facilitative effect whereas illustrations highlighting conflicting or irrelevant information had an interfering effect but that these effects decreased as grade increased. These findings suggest that the suppression mechanisms hypothesized to support mental model building may become more efficient in the later primary grades among typically developing readers. However, the precise role that suppression mechanisms play in the accurate formation of near and far inferences among students in the secondary grades remains unclear. Thus, an important next step is to test their role in the formation of near and far inferences.

Hypotheses Based on an Integrated Model of Inference Making

First, building on the DIME model to include cognitive predictors such as working memory and suppression of irrelevant information from memory, we hypothesized that near inferences significantly influence the construction of far inferences. Reading component skills such as background knowledge, vocabulary knowledge, and strategy use exert both direct and indirect effects on far inferences, the latter resulting from direct effects on near inferences and the direct effect of near inferences on far inferences (see Figure 1).

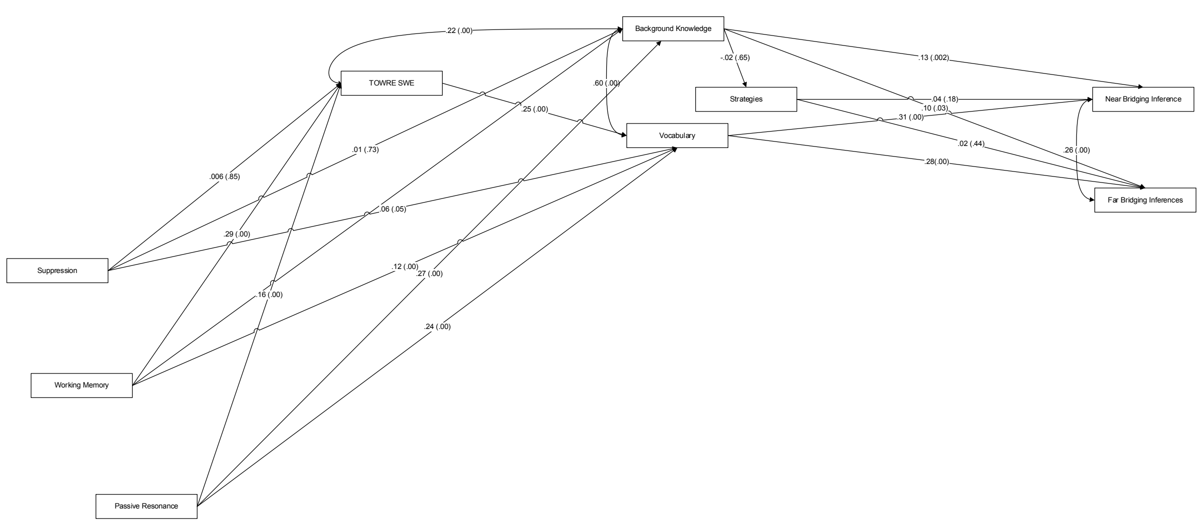

Figure 1
DIME Model Plus Measures of Cognitive Processing

Second, we hypothesized that in addition to background knowledge, vocabulary knowledge, and word reading efficiency, working memory and suppression of irrelevant information in working memory have both direct and indirect effects on near and far inferencing (see Figure 2) but that the direct effects will be larger for far inferences where information must be integrated across sentences separated in text.

Method

Participants

Participants (N = 1,085) were students in Grades 7-12 who participated in a larger study conducted in three cities and one suburb located near Houston, Texas (Ahmed et al., 2015). Students were enrolled in three middle schools serving Grades 7-8 and five high schools serving Grades 9-12 and were selected to participate in the study as either struggling or adequate comprehenders. The percentage of students qualifying for free or reduced-price lunch was 64.8% and the percentage of male students was 51.7%. The average age of the sample was 15.55 years (1.84 years), with approximately 22.2% of African American descent, 50.6% Hispanic, 22.9% white, and 4.3% other.

Students defined as struggling comprehenders performed at or below a scale score of 2150 on their first attempt on the Texas Assessment of Knowledge and Skills (TAKS; Texas Educational Agency, 2004) in the spring prior to the year the study was conducted (n = 472). Adequate comprehenders obtained scale scores greater than 2150 (n = 613). Students were excluded from participating in the study if they were identified by their schools as Limited English Proficient (LEP), if their English language arts instruction was provided by a LEP teacher, if they had a significant disability, or if their decoding skills were at or below the 20th percentile as measured by the Woodcock Johnson-III, Letter Word Identification subtest (WJ-III; Woodcock et al., 2001).

Measures

Component Skills Measures Based on DIME Model

Test of Word Reading Efficiency (TOWRE; Torgesen et al., 1999). The TOWRE is an individually administered assessment of word reading fluency. The Sight Word Efficiency (SWE) subtest asks students to read a list of 104 real words as accurately and rapidly as possible; the number of words read accurately in 45 seconds is recorded. The Phonemic Decoding Efficiency (PDE) subtest asks students to read a list of 63 nonwords as accurately and rapidly as possible; the number of nonwords read accurately in 45 seconds is recorded. The composite standard score was used in analyses with an alternate-form reliability exceeding .90 for students in the secondary grades.

Gates MacGintie Reading Test-Background Knowledge Test (GMRT-Knowledge Test; Ahmed et al., 2014). The Gates MacGinitie Reading Test-Background Knowledge Test is group-administered assessment of the word and world knowledge deemed to be necessary to understand the comprehension passages and questions on the

Gates MacGintie Reading Test. All students in our study took the GMRT-Knowledge Test 10-12, which consists of 29 items – 7 word items and 22 world items – that correspond with the GMRT Grades 10-12 Reading Comprehension. Cronbach's alphas for the Grade 10-12 form range from .58 to .77 for raw scores and .58 to .75 for standardized scores.

Gates MacGinitie Reading Tests, Vocabulary subtest (GMRT; MacGinitie et al., 2000). This 45-item, norm-referenced assessment of reading vocabulary may be administered individually or in group. Each test word is presented in a short phrase intended to suggest a part of speech but not to provide clues to the word's meaning. The student is expected to select the word or phrase that most closely means the same as the test word. Alternate-form reliability coefficients for Forms S and T for Grades 7-9 range from .83 to .89 and from .75 to .88. for Grades 10-12.

Contextualized Reading Strategy Survey (CReSS; Denton et al., 2015). The CReSS is a 49-item survey designed to assess learning and reading comprehension strategies that students might use when reading school material. Items were contextualized in the present study by first presenting a short scenario outlining a general reading activity (such as reading a social studies text book, reading a story from an English textbook, reading a self-selected non-fiction book, or reading articles from the internet) and then providing specific prompts related to that reading activity. Five response categories include (a) I almost never do this; (b) I rarely do this; (c) I sometimes do this; (d) I usually do this; and (e) I almost always do this. Cronboach's coefficient alpha for Grades 7-12 exceed 0.66 for each subscale. For this study the total score was reported.

Memory and Suppression Measures

Woodcock-Johnson III Test of Cognitive Abilities, Numbers Reversed subtest (WJ-III; Woodcock et al., 2001). The Numbers Reversed subtest assesses students' verbal working memory span by asking students to repeat increasingly longer series of dictated numbers in reversed order. Internal consistency exceeds .90 for students in the secondary grades.

Goldman Fristoe Recognition Memory Test (GFW-R; Goldman et al., 1974). The Goldman Fristoe Recognition subtest is an individually administered computerized task that measures recognition of previously encountered words from memory and is considered a passive resonance task. Students listened to a list of words through the headphones of a computer. After listening to each word, the student was asked to say "yes" if they had previously heard the word or "no" if they had not. The task was comprised of five practice items and 110 test items (i.e, 55 words with each word repeated twice). Of the 110 items, there were six 0-back items, six 1-back items, six 2-back items, six 3-back items, seven 4-back items, six 5-back items, six 6-back items, six 7-back items, and six 8-back items. The order of the *n*-back items was randomized. Reliability coefficients (Kuder-Richardson 20 [KR-20]) from the parent study sample for the secondary grades ranged from .71 to .93 (mean = .88) for raw scores and from .88 to .94 (mean = .90) for standardized scores.

Cognitive Verbal Interference (Barnes et al., 2015). The Proactive verbal interference task was an individually administered computerized task that measures the suppression of irrelevant information. The task comprises 4 practice trials and 24 test trials, with all trials consisting of either a single or double block structure. The task began with a visual prompt "Ready?" followed by an audible list of four words. In the single block trial, the word list was followed by the visual presentation of a question mark (?). In the double block trial, the word list was followed by an "X," which was followed by a list of four words, and a questions mark (?). The "X" prompted students to focus on remembering the second list while forgetting the first list. To prevent rehearsal, students shadowed 20 numbers. Next, students were given a category cue to prompt recall of a word from the list. Eight double block trials consisted of "interference" trials; eight consisted of "no-interference." Reliability coefficients for the interference trials (KR-20) for the secondary grades range from .45 to .67 (mean = .63) for raw scores, and from .45 to .66 (mean = .63) for standardized scores.

Near and Far Inference-Making Measure

Bridging Inference Test (Bridge-IT; Barth et al., 2015). The Bridge-IT is a computerized near and far inference task measuring the effect of textual distance on a student's ability to judge whether a continuation sentence is consistent or inconsistent with prior text (see Table 1). Students first see the word "Ready" on the computer screen followed one second later by a five-sentence passage. After reading the passage, students are directed to press the spacebar. The passage is then removed, and an asterisk appears in the middle of the screen to signal the presentation of the continuation sentence. Students are prompted to read the continuation sentence and press the green button on the screen if the continuation is consistent with the story and the red button if inconsistent with the story. Students receive a testlet comprising two practice items, and eight near-consistent, eight far-consistent, eight near-inconsistent, and eight far-inconsistent test

Table 1
Example Passage From Bridging Inferences Task

Passage: Near textual distance	Passage: Far Textual Distance
Alan sits in the back row of his fourth-grade classroom.	Alan does not like getting in trouble with his teacher.
He sits beside two other boys who tell very funny jokes.	Alan sits in the back row of his fourth-grade classroom.
Alan heard one of them tell a very funny joke.	He sits beside two other boys who tell very funny jokes.
The two boys giggled.	Alan heard one of them tell a very funny joke.
Alan does not like getting in trouble with his teacher.	The two boys giggled.
Continuation: Good Alan kept quiet.	Continuation: Good Alan kept quiet.
Continuation: Poor Alan laughed loudly.	Continuation: Poor Alan laughed loudly.

items. The total Near (near-consistent + near-inconsistent) and Far (far-consistent + far-inconsistent) raw scores (i.e., the proportion correct) were used in the analyses. Average reliability coefficients (KR-20) for students in the secondary grades are .85 for near-consistent; .87 for near-inconsistent; .83 for far-consistent; and .87 for far-inconsistent items.

Procedure

Examiners completed an extensive training program on the administration, scoring, and verification process for each assessment. Prior to working with study participants, they were required to demonstrate at least 95% accuracy in the administration, scoring, and verification of each assessment during a practice session. All assessments were completed at the students' school.

Analytic Plan

We chose to control possible effects of student grade/age on inference making and the effects of different predictors on inferences, focusing instead on the average relationship across grades. To do so, we first standardized all scores within grades, thereby removing differences between grades in means and variances across the set of measures. Then, using the statistical software MPLUS (Version 7; Muthen & Muthen, 1998-2002), we estimated the base model and additional nested models (see Figures 1 and 2) using Full Information Maximum Likelihood. Model fit was indicated by values of (a) chi-square probability, (b) Comparative Fit Index (CFI), (c) Tucker-Lewis Index (TLI), (d) Root Mean Square Residual, and (e) Standardized Root Mean Residual (SRMR) (Hu & Bentler, 1999). Akaike Information Criterion (AIC) and Baynesian Information Criterion (BIC) were also used.

Results

Descriptive Statistics

Table 2 shows descriptive statistics for all measures. Data were first screened for normality, skewness, and kurtosis. All variables were approximately normally distributed, and no variables had high skew or kurtosis. Some data were missing on each of the following measures: Bridging Inference Test-Near .2%, Bridging Inference Test-Far .6%, TOWRE 5%, GMRT-Background Knowledge Grades 10-12 9%, GMRT-Vocabulary 7%, CReSS 1%, WJ-III Numbers Reversed 2%, Goldman Fristoe Resonance 13%, and Proactive Verbal Interference 3%. Because students completed computerized and paper-pencil assessments on different days and times, variability in the amount of missingness occurred due to student absences. However, the bulk of the missing data were data missing completely at random. Therefore, we used Full Information Maximum Likelihood to estimate the models.

Relations of Bridging Inferences, Reading Component Skills, and Cognitive Processes

Relations between performance on Bridge-IT Near and Far, TOWRE, GMRT Background Knowledge, GMRT Vocabulary, TOWRE, CReSS, WJ-III Numbers Reversed, Goldman Fristoe Recognition Memory, and Proactive Verbal Interference were examined using Pearson's correlation coefficients. As seen in Table 3, Bridge-IT-Near was positively correlated with all measures, whereas Bridge-IT-Far was positively correlated with all measures except strategy use. Bridge-IT Near and Far were most highly correlated with GMRT-Vocabulary.

Table 2
Descriptive Statistics Total Sample

Variable	Mean	Standard Deviation
Bridging Inferences Test – Near	.79	.17
Bridging Inferences Test – Far	.59	.18
Test of Word Reading Efficiency	93.14	10.03
Gates MacGinitie Reading Test-Background Knowledge	21.18	5.28
Gates MacGinitie Reading Test-Vocabulary	94.43	11.43
Contextualized Reading Strategy Survey	3.24	.64
Woodcock Johnson-III Numbers Reversed	93.26	13.27
Goldman Fristoe Resonance	43.44	9.68
Cognitive Verbal Interference	4.29	1.69

Note. N = 1,085. Bridging Inferences Test – Near raw score, proportion correct. Bridging Inferences Test – Far raw score, proportion correct. Test of Word Reading Efficiency Sum Score. Gates MacGinitie Reading Test-Background Knowledge 10-12 raw score. Gates MacGinitie Reading Test-Vocabulary standard score. Contextualized Reading Strategy Survey average raw score for four scales. WJ-III Numbers Reversed standard score. Goldman Fristoe Resonance standard score. Cognitive Verbal Interference – Interference Trials raw score for Proactive Verbal Interference.

Modeling Predictors of Bridging Inferences

Model 1 represents the base model. The base model includes the component skills of word reading efficiency (i.e., TOWRE), vocabulary knowledge (i.e., GMRT Vocabulary), background knowledge (i.e., GMRT World Knowledge), strategy use (i.e., CReSS), near inference making (Bridge It-Near) and far inference making (Bridge It-Far) as well as the passive resonance in memory (i.e., Goldman Fristoe Recognition), working memory (i.e., WJ-III Numbers Reversed), and suppression of irrelevant information from working memory (i.e., Proactive Verbal Interference). In this model the correlation between near and far inference making was fixed to 0. Model 1 provided a poor fit to the data (RMSEA = .098; SRMR = .051; CFI = .899; TLI = .762) (see Table 4) and accounts for 18% of the variance in near and 13% of the variance in far inference making.

Hypothesis 1

Model 2 (depicted in Figure 2) examined whether reading component skills such as background knowledge, vocabulary knowledge, and strategy use exert both direct and indirect effects on far inferences, the latter resulting from direct effect on near

Table 3
Correlation Matrix

	1.	2.	3.	4.	5.	6.	7.	8.	9.
1. Bridge-IT – Near	1								
2. Bridging-IT – Far	.35†	1							
3. TOWRE	.14†	.13†	1						
4. GMRT Knowledge	.39†	.30†	.12**	1					
5. GMRT Vocabulary	.41†	.37†	.25†	.70†	1				
6. CReSS	.08**	.04	.05	.08*	.08*	1			
7. WJ-III Numbers Reversed	.13†	.18†	.32†	.14†	.23†	-.01	1		
8. Goldman Fristoe Resonance	.20†	.17†	.04	.13†	.16†	.05	.19†	1	
9. Cognitive Verbal Interference	.26†	.17†	.18†	.28†	.32†	.10**	.16†	.15†	1

Note. Bridging Inferences Test (Bridge-IT) – Near raw score, proportion correct. Bridging Inferences Test (Bridge-IT) – Far raw score, proportion correct. Test of Word Reading Efficiency (TOWRE) Standard Score composite. Gates MacGinitie Reading Test (GMRT)-Background Knowledge raw score. Gates MacGinitie Reading Test (GMRT) Vocabulary standard score. Contextualized Reading Strategy Survey – average raw score for 4 subscales. Woodcock Johnson-III (WJ-III) Numbers Reversed standard score. Cognitive Verbal Interference – Interference Trials raw score for Proactive Verbal Interference. Goldman Fristoe Resonance (GFR) standard score.
*Significant at $p < .05$. **Significant at $p < .01$. †Significant at $p < .0001$.

Table 4
Model Fit Indices

	CFI	TLI	RMSEA	SRMR	AIC	BIC	χ^2	*df*	*p*
Model 1	.899	.762	.098	.051	13800.35	13949.60	136.86	14	<.001
Model 2	.949	.871	.072	.041	13740.47	13894.54	74.98	13	<.001
Model 3	.985	.931	.053	.023	13702.46	13885.41	24.97	7	<.001

inferences and the direct effect of near inferences on far inferences. Model 2 provided an adequate fit to the data (RMSEA = .072; SRMR = .041; CFI = .949; TLI = .871). The model also accounted for 19% of the variance in far inferencing.

Near inferencing had the largest direct effect on far inferencing ($\beta = .27$, $p < .001$), followed by vocabulary knowledge ($\beta = .20$, $p < .001$). Interesting, the direct effect of background knowledge ($\beta = .06$, $p = .16$) and strategy use ($\beta = .01$, $p = .66$) on far inferencing was not significant. Regarding indirect effects, vocabulary knowledge ($\beta = .084$, $p < .01$), background knowledge ($\beta = .036$, $p < .01$), and word reading efficiency ($\beta = .069$, $p < .01$) had significant indirect effects on far inference making. The indirect effect of strategy use was not significant ($\beta = .011$, $p = .19$).

Regarding near inference making, both vocabulary knowledge ($\beta = .31$, $p < .001$) and background knowledge ($\beta = .13$, $p = .002$) had significant direct effects on near inference making.

Hypothesis 2

Model 3 (depicted in Figure 3) examined whether passive resonance in memory, working memory, and suppression of irrelevant information from working memory had significant direct and indirect effects on near and far inferencing, the latter resulting from direct effect on near inferences and the direct effect of near inferences on far inferences. Model 3 fit the data well (RMSEA = .053; SRMR = .023; CFI = .985; TLI = .931). Approximately 20% of the variance in far inferencing and 21% of the variance in near inference making was accounted for.

The direct effects of working memory ($\beta = .08$, $p = .02$), suppression ($\beta = .07$, $p = .03$), near inferencing ($\beta = .25$, $p < .001$), and vocabulary knowledge ($\beta = .18$, $p < .001$) on far inferencing were all significant (see Table 5). The direct effects of passive resonance in memory ($\beta = .01$, $p = .73$) and background knowledge ($\beta = .06$, $p = .19$) on far inferencing were not significant. Regarding indirect effects, suppression ($\beta = .05$, $p < .001$), working memory ($\beta = .06$, $p < .001$), and passive resonance in memory ($\beta = .21$, $p < .001$) all had significant indirect effects on far inference making as well as word on reading efficiency ($\beta = .06$, $p < .001$), background knowledge ($\beta = .03$, $p < .01$), and vocabulary knowledge ($\beta = .07$, $p < .001$).

The direct effects of suppression ($\beta = .13$, $p < .001$), passive resonance in memory ($\beta = .12$, $p < .001$),

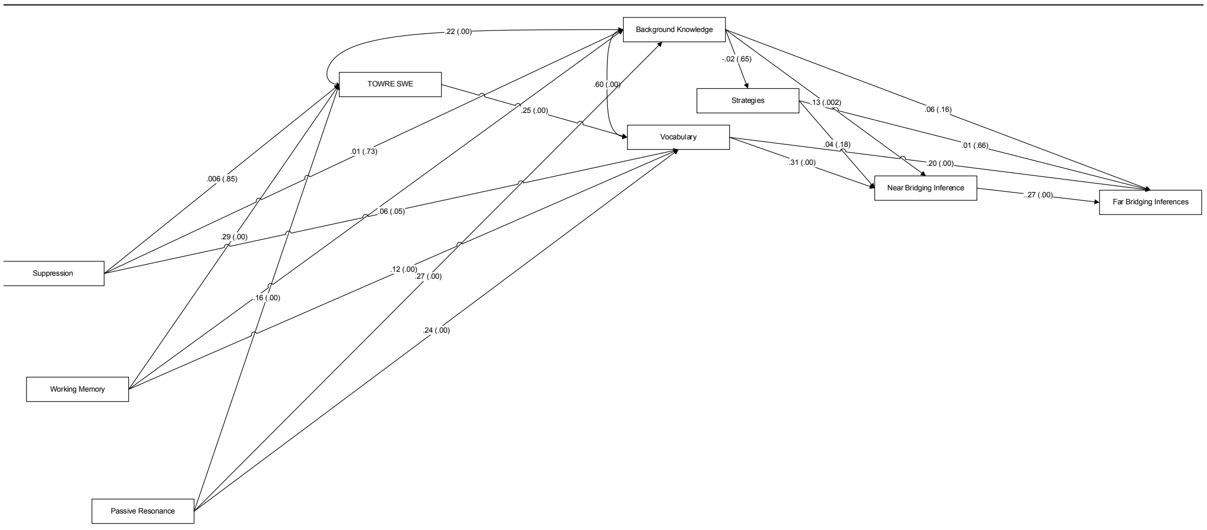

Figure 2
Model 2 Near Bridging Inferencing Predicting Far Bridging Inferencing

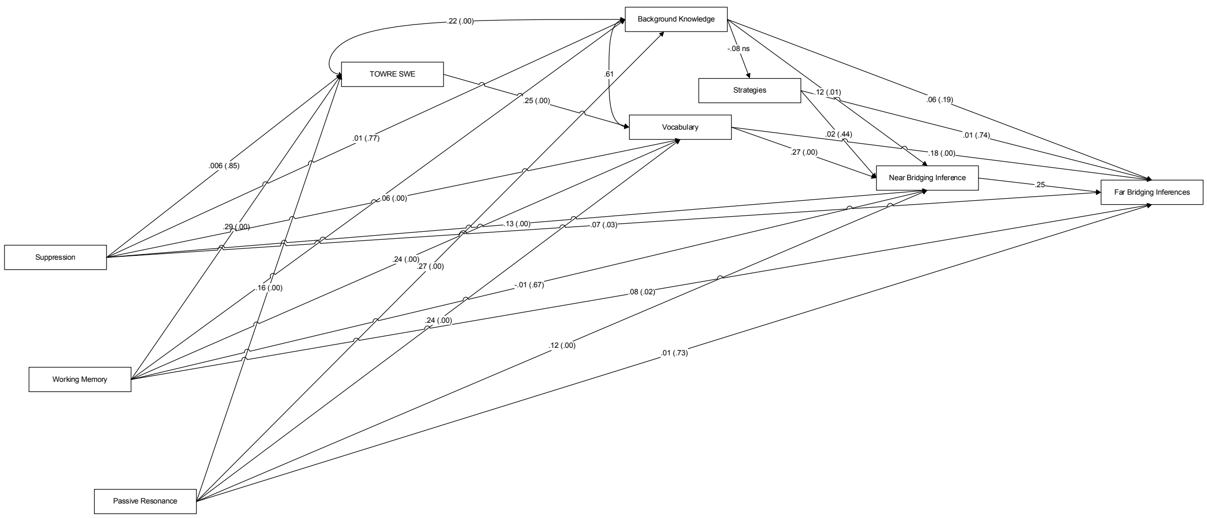

Figure 3
Model 3 Cognitive Processes Predicting Near and Far Bridging Inferencing

background knowledge (β = .12, *p* = .005), and vocabulary knowledge (β = .27, *p* < .001) on near inferencing were significant. The direct effects of working memory (β = -.01, *p* = .67) and strategy use (β = .02, *p* =.44) were not significant. Regarding indirect effects, working memory (β = .07, *p* <.001), passive resonance in memory (β = .11, *p* <.001), and word reading efficiency (β = .07, *p* <.001) all had significant indirect effects on near inference making; the indirect effect of suppression (β = .02, *p* = .129) was not significant.

Discussion

Deeply understanding text requires that the reader construct meaningful connections among ideas in the text. Theory suggest that this process is inferential in nature (Kintsch, 1988). It depends on efficient word reading and word and world knowledge; is performed within the limits of the reader's working memory capacity; and requires that the reader identify what information is relevant and should be integrated to maintain coherence (Florit et al., 2011; Kintsch, 1988).

Results of this study show that near inferencing had the largest direct effect on far inferencing followed by vocabulary knowledge. Vocabulary knowledge had the largest direct effect on near inferencing. Further, suppression of irrelevant information from working memory significantly impacted the accurate formation of near and far inferences after controlling for reading related skills. Finally, passive resonance in memory uniquely influenced the formation of near inferences whereas working memory played a unique role in the formation of far inferences. These results are further discussed below.

The Role of Near Inferences in the Formation of Far Inferences

First, the direct effect of near inference making (.27) on far inference making was the largest in magnitude relative to the direct effects of strategy use (non-significant), vocabulary knowledge (.20), and background knowledge (nonsignificant). These results support the hypothesis that near inferencing plays a significant role in the formation of far inferences. However, they also suggest that inferencing may not be a strictly categorical distinction. Instead, as Florit et al. (2011) and Kendeou (2015) propose, inferencing might represent a general cognitive skill influenced by factors such as vocabulary, background knowledge, and cognitive processes like suppression and working memory. The significant direct effects of near inferencing on far inferencing observed in this study support this perspective, highlighting shared mechanisms underlying these processes. Recognizing inferencing as a general skill suggests that interventions should focus on developing foundational cognitive and linguistic skills that support both near and far inferences. Teaching strategies that enhance global coherence building could simultaneously benefit both types of inferencing.

Table 5
Direct and Indirect Effects of Predictors on Near and Far Inference Making for Model 3

Variable	Direct Effect	Indirect Effect	Total Effect
Far Inference Making			
Suppression of Irrelevant Information From Working Memory	.07*	.05†	.12†
Working Memory	.08*	.06†	.13†
Passive Resonance in Working Memory	.01 *ns*	.12*	.13†
Word Reading Efficiency	-	.06†	.06†
Background Knowledge	.06 *ns*	.03**	.089 *ns*
Vocabulary Knowledge	.18*	.07†	.24†
Strategy Use	.01 *ns*	.01ns	.02 *ns*
Near Inference Making	.25†	-	.25†
Near Inference Making			
Suppression of Irrelevant Information from Working Memory	.13†	.02 ns	.15†
Working Memory	-.01 *ns*	.07†	.06 *ns*
Passive Resonance in Working Memory	.12†*	.11†	.23†
Word Reading Efficiency	-	.07†	.07†
Background Knowledge	.12**	-	.12**
Vocabulary Knowledge	.27†	-	.27†
Strategy Use	.02 *ns*	-	.02 *ns*

*Significant at $p < .05$. **Significant at $p < .01$. †Significant at $p < .0001$; *ns* = not significant.

Direct and Indirect Effects of Cognitive Processes on Near and Far Inferences

We also hypothesized that over and above reading reading-related skills, cognitive processes would impact the formation of near and far inferences. Results of this study suggest that suppression of irrelevant information from working memory directly impacts the accurate formation of both near and far inferences. In addition, passive resonance in memory influences the formation of near inferences, where the information required to form the inference is close together in text (i.e., 1-2 sentences). Working memory plays a role in the formation of far inferences where information required to form the inference is separated in the text (i.e., 5 sentences).

Why might these cognitive processes play a small but significant role in the formation of near and far inferences? First, it is important to note that in the current inference-making paradigm, each five-sentence story consisted of two opposing mental models. In the near condition, the first model was presented in the fourth sentence ("The two boys giggled."). The second model was presented in the fifth sentence ("Alan does not like to get into trouble with his teacher."). To judge the continuation of the story as "consistent" or "inconsistent," the reader had to reject the first model (i.e., "The two boys giggled.") presented in the fourth sentence of the paragraph. The near condition placed the correct model immediately before the continuation of sentence. Thus, it seems reasonable to hypothesize that the correct model was actively resonating in memory, giving the reader the opportunity to make the correct inference and judge the continuation as "consistent" or "inconsistent."

In the far condition, the first and appropriate model was presented in the first sentence of the story (i.e., that Alan does not like to get into trouble with his teacher), leaving the need for the second model (i.e., the two boys giggled) presented in the last sentence of the paragraph, to be suppressed in order to make the correct inference and judge the continuation as "consistent" or "inconsistent." Because key information from the text was mentioned only once and was presented in the first sentence, there is a lower probability that the first mental model is easily recognized without reactivation through potentially more strategic search after meaning processes. Consequently, the reader must draw more heavily on cognitive processes that support the activation and integration of relevant information from working memory while simultaneously suppressing irrelevant information that should not be integrated into the evolving mental model of text.

These results align with Florit et al. (2011), who showed that although processing information explicitly stated in the text requires cognitive resources, the cognitive demand is less than what is required to construct and integrate ideas that are implied. Collectively, this growing body of literature suggests that the cognitive resources used to form meaningful connections between ideas in the text and general knowledge are influenced by features of the text.

Caveats

Although this study hypothesized that near inferencing plays an important role in the formation of far inferences, inferencing likely represents a general skill differentially influenced by lower-, higher-level, and cognitive skills (Florit et al., 2011; Kendeou, 2015). As a general skill, the reader's knowledge as it relates to the text, willingness to hypothesize about future events in the story, strategies or goals for comprehension, standards of coherence, manner in which the information is presented (e.g., text type, difficulty level, syntactic complexity, and referential and causal cohesion) (Graesser et al., 2004; van den Broek et al., 2005), and cognitive processes may all influence both the rate and accuracy with which inferences are made in the general sense and not differentially by type. The level of understanding a reader seeks to achieve may influence the extent to which these passive and strategic inferential processes are deployed.

Limitations

There are four main limitations of the present study. First, our sampling strategy oversampled for students with reading disabilities and reading difficulties but excluded students with word reading accuracy scores that fell below the 20^{th} percentile. A consequence of this sampling plan was a sample of students in which decoding skills were truncated. A second limitation relates to the measures used to assess the constructs of near and far inference making, strategy use, passive resonance of information in working memory, and suppression of irrelevant information from working memory. In each case, the measure was researcher developed because a standardized assessment possessing high technical adequacy is not currently available for students in the secondary grades. It is likely that the construct validity of the measure used is lower than what is considered appropriate, and as a result the estimated direct and indirect effects are biased due to measurement error. Future validation would strengthen the results of the study and the importance of including these types of measures in future research. The third limitation also relates to measurement. The study used a regression-based approach that measured each construct with a single indicator. As a result, it is highly likely that the predictor variables and outcome variables were measured with error resulting in over- or underestimation of the direct effects, indirect effects, and amount of variance account for. Fourth, only 18-20% of the variance in inference making was accounted for. This suggests that either important reading, reading-related, or cognitive skills supporting near or far inference making were not included in the model, or skills were measured differently that previous validation studies of the DIME model, thereby resulting in smaller direct effects and variance accounted for. It is also possible that additional predictors, such as motivation, might explain further variance or that alternative modeling approaches might improve explanatory power. Finally, variability in missing data across measures may have influenced the findings.

Conclusions

This study sought to advance our knowledge about the skills that directly and indirectly influence inferencing among adolescent readers, to inform future research that empirically tests recommended practices. Results showed that inferences requiring the integration of information that is separated in text is influenced by the reader's accuracy in forming near inferences, vocabulary knowledge, as well as working memory capacity that permits the retrieval of relevant information from long-term memory stores while suppressing irrelevant information. Near inferences are influenced by one's vocabulary and world knowledge as well as cognitive processes that allow the reader to easily recognize common ideas in text or memory while suppressing information not related to the topic. While the effects of these cognitive processes are unique, they are small.

These findings suggest that readers should be explicitly taught how to make inferences as part of general reading instruction. First, instruction should model how to (a) identify important ideas that are relatively close together in text and then

(b) connect those ideas to produce meaning. Instruction will show readers how to fill conceptual gaps between clauses and adjacent sentences. Next, readers should be taught how to activate relevant background knowledge that might more completely fill in conceptual gaps. Readers will benefit from instruction that helps them to what type of knowledge fits best. In other words, students will rule out irrelevant knowledge and retain relevant knowledge. Then, as inferencing improves in accuracy and efficiency, the distance separating ideas in text should be expanded. In this way readers are forming inferences within and across paragraphs of text. Finally, instruction should model for students what it means to deeply understand text. In other words, each text should be read with a purpose, goal, or standard in mind. Thus, goals for reading should be outlined by the teacher to ensure that the text is accessible and goal for reading achievable.

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