# THE ROLE OF ILLUSTRATIONS IN CHILDREN'S INFERENTIAL COMPREHENSION

A Thesis

Presented to

The Faculty of Graduate Studies

of

The University of Guelph

by

MEREDITH M. PIKE

In partial fulfillment of requirements

for the degree of

Master of Arts

August, 2008

*Your file Votre référence*
*ISBN: 978-0-494-47811-0*
*Our file Notre référence*
*ISBN: 978-0-494-47811-0*

ABSTRACT

THE ROLE OF ILLUSTRATIONS IN CHILDREN'S INFERENTIAL COMPREHENSION



Meredith M. Pike
University of Guelph, 2008

Advisor:
Professor Marcia A. Barnes



Illustrations are a salient source of information in children's books yet their effect on children's reading comprehension has only been studied through literal, factual recall. The purpose of the current study was to determine the effect of illustrations on some of the higher-order component skills of reading comprehension, namely making inferences. Identical short stories were presented under different illustration conditions, with pictures that represented different parts of the story. Participants were 73 children from grades two to six. Illustrations both facilitated and interfered with inferencing ability, depending on the type of information depicted, but this effect was reduced as grade increased. Additional findings were that the overall ability to make inferences increased with age and working memory was a significant predictor of this skill. Results are discussed in relation to cognitive and developmental models of comprehension.

Acknowledgements

I would like to express my sincere gratitude to the many people who made this thesis possible. First and foremost, I would like to thank my advisor, Dr. Marcia Barnes for her guidance and mentorship, for challenging me to dig deeper, and for always believing in my abilities as a researcher. I would also like to thank my committee member, Dr. Rod Barron, for his valuable comments throughout the various revisions of this thesis. Thank you to Dr. Mary Ann Evans for taking the time to read my thesis and chair my defence. I am hugely indebted to my partner in crime, Amber Johnston, who was completely selfless in helping me with all aspects of this project, but in particular with collecting the data, where she put my needs above her own. Without her support and generosity, the data collection would have not been possible, and without her friendship, it would have been a lot less fun. I must also say an extra special thank you to the staff and students from the Hamilton Wentworth Catholic District School Board, who were so welcoming and helpful through this process. My fellow cohort members, Lianne, Kim, Bronwen, Bev, and Sarah have been there with me every step of the way and I could not have asked for kinder, more understanding or more wonderful friends to experience graduate school with. I am so grateful to my parents, Marilyn Girouard and Lorne Pike for their unwavering support, encouragement, and love during of all my pursuits, academic and otherwise. Thank you for instilling in me the value of education and for teaching me to believe in myself – I love you both. Finally, I would like to dedicate this thesis to my partner, Richard Jordan. There are no words to express how instrumental your love, encouragement and patience have been during this process. I am so grateful for the sacrifices you have made for me to get to where I am today and love you very much.

Table of Contents

List of Tables

# List of Figures

# The Role of Illustrations in Children's Inferential Comprehension

The ultimate goal of reading, whether for learning or for pleasure, is for understanding. During comprehension, the reader generates a mental representation of the situation described by the text. This is a complex task that relies on a number of prerequisite decoding and language skills such as fluent and accurate word recognition, and knowledge of vocabulary and syntax. In addition to these more basic skills, there are a number of higher-order language and cognitive processes that are important, such as the ability to make inferences. In addition to the written text, children's books typically include illustrations, providing another source of information to be processed in conjunction with the words. The present study investigated the role of illustrations in the inferential comprehension of children in grades two to six.

## *Models of Reading Comprehension*

Several different theories and cognitive models have been proposed to explain the process of reading comprehension. The development of a mental representation of the situation described by the text is an element that is common to all major theories of reading comprehension (Oakhill & Cain, 2007), though theories differ somewhat in their explanations of how these representations are developed. For example, Kintch's (1988) construction-integration model refers to the coherent representation of the text as a situational model. According to this theory, two processes work cyclically to build the situational model. First, all prior knowledge associated with the incoming information is activated (construction), resulting in a large amount of activated information, much of which is unnecessary for understanding the text. The relevant parts are identified and are integrated to form a coherent representation (integration). This results in a cognitive representation that reflects the interaction between information provided by the text and the reader's prior knowledge. Similarly, Johnson-Laird (1983) proposed that the development of the mental representation of the text goes beyond the literal meaning to embody spatial, temporal, causal, motivational, and person and object related information in what is called a mental model. As the reader progresses through the text, the mental model is continuously updated as new information is read and interpreted (Zwaan & Madden, 2004).

A related, but somewhat different framework was proposed by Gernsbacher (1990). The Structure Building Framework hypothesizes that the mental representation or "structure" is built from memory nodes that contain all previously comprehended information and become activated by incoming information. If the information held by the activated nodes is relevant for structure building, their level of activation is enhanced (similar to Kintsch's process of integration). Where this framework differs from Kintsch's model, is that it requires a further process, called suppression. If the information contained by the nodes is not relevant for ongoing comprehension, their level of activation is suppressed and the reader shifts to form a new structure or substructure (Gernsbacher & Faust, 1991). This frees up memory resources, which then become available for the information activated by subsequent sentences and paragraphs. The process of activating relevant information, updating the model, and suppressing irrelevant information continues throughout the reading process, allowing the reader to make connections between the relevant information, both within and outside of the text, in order to develop a coherent understanding (Gernsbacher, 1990). Several studies have reported that poor comprehenders lack the ability to suppress irrelevant information (e.g., Barnes, Faulkner, Wilkinson, & Dennis, 2004; DeBeni & Palladino, 2000; Gernsbacher, 1993).

### *Inferencing Skills*

Making inferences is one of the processes that contributes to the construction of the mental representation of the situation described by the text. Inferences are required to connect ideas within the text and fill in details that are not explicitly presented in the text. The ability to make inferences has been found to be a strong predictor of reading comprehension in a number of studies (Cain & Oakhill, 1999; Cain, Oakhill, & Elbro, 2003; Cain, Oakhill, & Lemmon, 2004). Skilled comprehenders make many different types of inferences as they proceed through text, but one type in particular, bridging inferences, is considered essential for developing and maintaining a coherent understanding (Kintsch, 1994). Bridging inferences require the reader to integrate two pieces of explicitly stated information from within the text, in order to maintain coherence.

Developmental studies of inference making have found that this skill increases with age (Casteel & Simpson, 1991; Johnston, Barnes, Davis, & Desrochers, 2006). While young children are able to make some of the same types of inferences as older children and adults, they are less likely to do so spontaneously and are more successful when prompted or cued (Paris & Carter, 1973; Paris & Lindauer, 1976). The consistent and spontaneous making of inferences appears to develop around grade three (Paris & Lindauer, 1976; Paris, Lindauer, & Cox, 1977).

Inferencing ability is also affected by certain text-based factors, such as the distance in the text between the ideas that need to be integrated, as well as certain child-based factors, such as the working memory abilities of the reader. When the integration of information that is separated within the text is required, younger children and less skilled comprehenders are more affected by the separation than older children and more skilled comprehenders (Barnes et al., 2004; Johnston, 2006; Schmidt & Paris, 1983; Schmidt, Paris, & Stober, 1979). Inference making also appears to involve a strong working memory component (Barnes, Johnston, & Dennis, 2007; Cain, Oakhill, & Bryant, 2004). Both children and adults with reading comprehension problems have lower performance on working memory tasks (Just & Carpenter, 1992; Oakhill, 1993; Swanson & Berninger, 1995). Working memory can be thought of as the "work space" where information is processed, stored, and integrated; therefore limited working memory capacity has consequences for the ability to make inferences (Cain et al., 2004). It has been found that reducing the processing load for poor comprehenders increases their ability to make inferences. Specifically, when Barnes and Dennis (2001) cued children with comprehension difficulties to the fact that an inference was necessary and the relevant information needed to make the inference had just been retrieved (thus reducing the processing load) they no longer demonstrated an inferencing deficit in comparison to the good comprehenders.

Making inferences involves the integration of information in the text into a coherent mental model that is the basis for comprehension. However, an efficient reader cannot make connections between all of the information that is read or between all prior knowledge that is activated. In order to determine which information is to remain activated and which is to be suppressed, the reader relies on contextual clues to determine if the incoming information coheres with the previously comprehended information

(Ackerman, 1988; Gernsbacher, 1990; Kintsch, 1991). For example, sentences that refer to previously mentioned concepts or those that maintain previously established time frames or locations are powerful cues that the information should be integrated into the current mental model (Gernsbacher, 1997). It has been proposed that one of the cues used by readers, especially young readers, to facilitate the development of the mental model are illustrations (Glenberg & Langston, 1992; Gyselinck & Tardieu, 1999).

### *Illustrations and Reading Development*

Children's books are often accompanied by an additional source of information that must be processed in conjunction with the text, namely illustrations. Illustrations play a prominent role in nearly all of the books that children use to learn to read. In the past few decades especially, illustrations have become increasingly salient and elaborate in children's books and often dominate each page of text (Brookshire, Scharff, & Moses, 2002; Willows, 1978). Although there is some research on the effect of illustrations on letter and word reading, very little is known about how illustrations affect reading comprehension. This is likely in part because the component skills of reading comprehension, and how these skills develop in children, are less well understood than is the case for word reading (Cain & Oakhill, 2007).

The findings regarding whether pictures are helpful or harmful to learning how to read words are inconsistent. For instance, one of the first skills children are taught is the relationship between letters and sounds, and certain types of pictures have been found to facilitate this process (Ehri, Deffner, & Wilce, 1984). Conversely, early word learning seems to be negatively affected by included pictures. Samuels (1967) was the first to report that pairing new words with identifying pictures interfered with children's ability to recognize the word in isolation, a finding that has been replicated by several other studies (see Peeck, 1987).

In addition to word recognition, it has also been found that pictures play a distracting role for children when they read longer chunks of text. For example, Willows (1978) found that when pictures were present with the text, children tended to read more slowly and less accurately. In addition, she reported that pictures had larger effects for younger children and for those who were less-skilled readers. More recent research has measured children's eye fixations while a parent or teacher is reading to them. These studies have found that children (aged four and five) spend most of the time looking at the illustrations that accompany the text, and very little time looking at the printed text itself (Evans & Saint-Aubin, 2005), suggesting that children of this age rely on the more salient stimuli to figure out the word. Researchers who argue that illustrations interfere with the process of learning to read often cite the focal attention hypothesis (Samuels, 1970), which proposes that illustrations compete with attention that would otherwise be devoted to orthographic detail, and thus have a distracting role and negative effect on children's reading.

Other researchers, however, have challenged the attention focal hypothesis, by arguing that typical reading development involves more than learning to recognize the orthographic structure of isolated words. An alternate explanation, the contextual hypothesis (Donald, 1983) is that learning to read requires the child to become efficient at attending to not only orthographic information, but also to semantic, syntactic, and if available, illustrated information. Donald (1983) argued that the focal attention hypothesis ignores the main purpose of reading, namely, comprehension. Because the goal of reading is to extract meaning from the text, children who are learning to read should draw on all available types of information to achieve this goal (Donald, 1983).

Nearly all of the studies aimed at assessing the influence of illustrations on children's reading comprehension have studied children's literal comprehension of the text (Moore & Skinner, 1985). By presenting text with and without corresponding illustrations, dozens of studies have demonstrated that pictures facilitate the ability to remember specific and concrete information from the text (McDaniel & Waddill, 1994; Peeck, 1994). For example, Haring and Fry (1979) had children read a short story paired with or without illustrations and then write down everything they could remember about it. They found that the children who had read the story with the pictures were able to recall more details and concluded that pictures improve comprehension. Also using a free recall task, O'Keefe and Solman (1987) concluded that pictures benefited comprehension for children in grade three but had no effect for children in grade five. Brookshire et al., (2002) measured comprehension by asking children questions about the text that required them to recall certain facts about the story. They found that those who had seen the text with pictures answered more questions correctly and concluded that illustrations improved comprehension. Although all of these studies assessed the effects of illustrations on children's reading comprehension, the only aspect of comprehension measured was literal understanding, or more specifically the effect of illustrations on memory for story details.

Although recall of information in the text is an important component of comprehension (Cain, 2006a), conclusions about the effects of illustrations on reading comprehension cannot be based solely on this ability. Rather, it is necessary to study how illustrations affect other aspects of comprehension, such as those components identified above in cognitive models of comprehension as being important for constructing coherent representations of the text, namely, inference making and mental model building. As well it is important to understand how illustrations interact with cognitive abilities associated with comprehension, such as working memory.

Illustrations could act as one of the contextual clues used by the reader to decide which pieces of information should remain activated in the mental model (Glenberg & Langston, 1992). Pictures that provide a salient depiction of relations between elements of the text may act as facilitators in the process of transforming text into a mental model. Certain illustrations could even be viewed as one possible expression of a mental model (Gyselinck & Tardieu, 1999). Thus, it is possible that pictures could be useful in reading comprehension to the extent that they accurately represent the parts of the text that are important to integrate and keep activated for comprehension.

It has also been suggested that illustrations may serve to reduce the demands on working memory when processing text (Marcus, Cooper, & Sweller, 1996). Illustrations are thought to be easier to process than text because their increased salience makes the relationships between the important elements in the text more transparent (Gyselinck & Tardieu, 1999). Referring to diagrams in expository text, Levin and Mayer (1993) argued that the perceptual clarity and conciseness of the visual representation of the text reduces the cognitive load, thus facilitating higher-order reasoning about the information, a finding consistent with several other studies (see Marcus et al., 1996). Whether illustrations have a similar effect for children during narrative comprehension, however, is unknown.

*The Current Study*

The purpose of the current study was to examine the effects of illustrations on reading comprehension using a design that is guided by current theories of reading comprehension. Whereas most previous work has asked whether illustrations affect reading comprehension, the present study was directed at learning about *how* illustrations affect reading comprehension. Specifically, the goal of the current study was to examine the effects of illustrations on children's ability to make bridging inferences, given the central importance credited to this type of inference in cognitive models of comprehension.

To study the ability to integrate information from within the text, Davis, Johnston, and Barnes (2006) developed the Bridging Inferences Task (BRIDGE-IT). The BRIDGE-IT consists of items that require the reader to make inferences between sentences separated by intervening text (Davis, Johnston, Barnes, & Desrochers, 2007). In order to make the correct inference, the child must connect information from a statement sentence to information in the multiple-choice alternative. This requires the child to keep the statement sentence activated while suppressing the information from the chunk of intervening text (Davis et al., 2007). Research with the BRIDGE-IT found that the ability to make bridging inferences increased with grade and that inferencing accuracy was predictive of reading comprehension skill on standardized measures (Johnston, 2006). The following is a sample item from the original BRIDGE-IT (the statement sentence is in bolded font and the correct answer is in italicized font):

> **It was the first week of April but the ground was still covered in snow.**
> Pete loves to garden and was excited to plant his flowers.
> Pete had been waiting all winter for warm weather.
> Pete was happy it was finally Spring.

Which is the best sentence to come next in the story?
*a) Pete spent the day inside his house planning his garden.*
b) Pete spent the day digging up weeds and planting flowers.
c) Pete spent the day outside playing at the water park.

In the above example, the statement sentence (the first sentence) activates a mental model that the ground is covered in snow. The remainder of the text creates a second mental model that is related to Pete's love of gardening. According to the Structure Building Framework, (Gernsbacher, 1990), in this example the reader must keep the model that the ground is covered in snow activated and suppress the model that Pete is excited to start gardening in order to make the correct inference: because the ground is covered in snow, Pete spent the day inside planning his garden. Importantly, had the first sentence (statement sentence) been absent from the story, the better sentence to continue the story would have been that Pete spent the day gardening.

To determine the effect of illustrations on bridging inferences, the BRIDGE-IT was adapted for the current study to include pictures. In this version, each item is represented under three conditions: activation, suppression, and text-only. In the *activation* condition, the item includes a picture that is related to the statement sentence, which is the sentence that must remain activated in order to make the correct inference. In the *suppression* condition, the item includes a picture that is related to the intervening chunk of text that represents a conflicting mental model; the information contained in this section must be suppressed in order to make the correct inference. The *text-only* condition contains no picture. If children make more correct inferences when the statement sentence is represented in picture format and/or make more errors when the intervening portion of the text is represented in picture format, this would suggest that illustrations influence what information remains activated in the mental model, facilitating or interfering with comprehension respectively.

The first goal of the current study was to determine the effect that the type of picture has on bridging inferences. It was predicted that overall, children would be most successful at bridging inferences on items where the illustration represents the statement sentence (activation condition) and make more errors on items where the illustration represents the portion that should be suppressed (suppression condition). The second aim was to assess the effect of pictures on inference making in younger and older readers. Although it was predicted that the ability to make bridging inferences would increase with age, since previous research has shown that younger readers are more dependent on contextual support to make inferences than older readers (Ackerman, 1988), it was expected that for older children, the pictures would not have as strong of an effect as they would with younger children. The third goal was to determine if illustrations facilitate comprehension by reducing the processing load in working memory. It was hypothesized that working memory would have a differential effect on the relationship between illustrations and inferencing ability. Specifically, it was predicted that working memory would be a significant predictor of inferencing in the suppression condition but not in the activation condition. An additional goal of the study was to assess the validity and utility of the experimental bridging inferences task as a measure of reading comprehension. This was assessed by determining if children's performance on the experimental task was predictive of their performance on a standardized test of reading comprehension.

# Methods

## *Participants*

Seventy-three native English-speaking children ranging from grades 2 through 6 (7 to 11 years-old) were recruited from a local school board to participate in the present study. The sample included 36 males and 37 females. Based on information from a parent questionnaire, students were excluded from participating in the study if they were enrolled in a special education class or had been identified with a learning disability, had major neurological or behavioural disorders (e.g., head injuries with hospitalization, autism, conduct disorder), or were being schooled in English as a second language. An additional inclusion criterion was that children had to have age-appropriate word reading abilities and vocabulary knowledge, as assessed by the Sight Word Efficiency subtest from the Test of Word Reading Efficiency (TOWRE; Torgeson, Wagner, & Rashotte, 1999) and the Picture Vocabulary subtest from the Woodcock-Johnson III (WJ-III; Mather & Woodcock, 2001). Participants were excluded if their score was one or more standard deviations below the mean on either of these tests.

## *Materials*

### *Word Reading Skill*

*Sight Word Efficiency Subtest from the Test of Word Reading Efficiency (TOWRE; Torgeson, et al., 1999).* This measure was included as a screener to ensure that the participants had adequate word reading ability. It is a valid, reliable, and efficient measure of word reading accuracy and fluency that assesses how many real words can be read accurately in 45 seconds. This subtest has a high degree of reliability, with test-retest reliability for 6 to 18 year olds ranging from 0.84 to 0.97 when tested within a two-week period. Furthermore, the manual reports strong relationships between this subtest and measures of text reading fluency, accuracy, and comprehension (predictive validity: 0.75 to 0.87).

*Vocabulary*

*Picture Vocabulary Subtest from the Woodcock-Johnson III (WJ-III; Woodcock, McGrew, & Mather, 2001).* A vocabulary measure was included to ensure adequate word meaning knowledge in participants. This measure requires the child to identify pictured objects. Each child begins with words that are grade appropriate and the items become increasingly difficult. The manual reports a median reliability of 0.77 in children aged 5 to 19.

*Working Memory*

*Auditory Working Memory Subtest from the Woodcock-Johnson III (WJ-III; Woodcock et al., 2001).* This subtest was included as the measure of verbal working memory. The child was asked to listen to a list of words, some of which were digits and some that were objects. The child was then required to reorder the information, repeating first the objects in sequential order and then the digits in sequential order. The lists become longer as the task progresses. This task requires the ability to hold information in immediate memory, divide the information into two groups, and shift attentional resources to the two new ordered sequences (Mather & Woodcock, 2001). This construct has a median reliability of 0.88 in the 5 to 19 age range.

*Standardized Test of Reading Comprehension*

*Paragraph Reading subtest from the Test of Reading Comprehension, third edition (TORC3-PR; Brown, Hammill, & Wiederholt, 1995*). On this subtest participants were asked to read a paragraph and answer five questions relating to the paragraph. One question assessed understanding of overall theme of the story by requiring the selection of the best title. Two questions assessed the ability to remember and identify details from the paragraph and two questions assessed the child's ability to make two types of inferences. The manual reports good test-retest reliability ($r = 0.81$) two months following the first administration.

*Bridging Inferences Measure*

*Bridging Inferences Task – Picture Version.* This task was designed to measure the effect of illustrations on the ability to make bridging inferences. It was comprised of 24, 5-sentence, story-like passages. The cover page included detailed directions, which were read to each participant. Each story was on a separate page and the children were instructed to turn the page when finished reading each story. Three sentences were given on the back of each page. The participants were told to choose the best sentence to come next in the story and they were not allowed to turn back to refer to the story they had just read. Each child progressed through the booklet at his/her own pace.

Each passage began with a statement sentence and was followed by four sentences of intervening text. The intervening text contained information that conflicted with the first mental model, as well as filler information that was irrelevant for making the inference, but was related to the development of the unfolding story. This setup was designed to cause the reader to develop two conflicting mental models. Choosing the correct sentence to come next in the story always required the reader to integrate the information that was stated in the first sentence and suppress information contained in the following section. Each item was presented under one of three conditions: (1) with a picture directly underneath the text that represented information from the statement sentence which must remain activated to make the correct inference (the "activation" condition); (2) with a picture directly underneath the text that corresponded to portion of the text which must be suppressed to make the correct inference (the "suppression" condition) and (3) with no picture at all (the control or "text-only" condition). An example of an item presented under all three conditions can be found in Figure 1.

Within each booklet of 24 items, there were 8 items in each condition presented in alternating order. Three versions of the booklet were created so that each item was presented in each condition, and each version was administered an equal number of times within each grade. The illustrations were in colour and purchased from websites. The interaction from a 3 (condition) by 3 (version) mixed ANOVA was not significant, indicating that performance in each condition was equal on all three versions.

Each of the three answer choices was designed to assess the child's ability to keep appropriate information activated in their mental model of the story. The correct answer always required integration of the information from the statement sentence. Of the two incorrect alternatives, one matched the conflicting mental model; choosing that answer was presumed to demonstrate a lack of suppression. The other incorrect alternative was not related to either model, and was thus considered neutral. The BRIDGE-IT Picture Version was based on a previous version called the BRIDGE-IT (Davis et al., 2007), which reported a parallel reliability coefficient of 0.73.

Activation Condition

Tim was very full because his mother had made him a very big lunch.
Tim went to Mike's birthday party in the afternoon.
The birthday party had an ancient Egypt theme.
At the party they played some video games and opened presents.
Mike's mom served a delicious birthday cake.

Text-Only Condition

Tim was very full because his mother had made him a very big lunch.
Tim went to Mike's birthday party in the afternoon.
The birthday party had an ancient Egypt theme.
At the party they played some video games and opened presents.
Mike's mom served a delicious birthday cake.

Suppression Condition

Tim was very full because his mother had made him a very big lunch.
Tim went to Mike's birthday party in the afternoon.
The birthday party had an ancient Egypt theme.
At the party they played some video games and opened presents.
Mike's mom served a delicious birthday cake.

Multiple Choice Alternatives

a) Tim asked for a big piece of cake.
*b) Tim asked for a little piece of cake.*
c) Tim asked for a balloon animal.

*Note.* The italicized answer is the correct answer.

*Figure 1.* Example of activation, text-only, and suppression conditions from the BRIDGE-IT Picture Version Task.

*Procedure*

Children were first seen individually in a quiet room at their school where they were given the Auditory Working Memory and the Picture Vocabulary subtests from the WJ-III, and the Sight Word Efficiency subtest from the TOWRE. Children were then seen on a different day, typically one to two weeks after the individual testing, in groups of up to six at a time to complete the BRIDGE-IT Picture Version and the Paragraph Reading Subtest from the TORC (Brown et al., 1995). Group testing was completed because the current study is part of a larger study being completed to develop comprehension tools that can be administered in group format. The experimenter sat at the table with the children and monitored their progress.

## Results

Participant characteristics and scores on standardized measures of word reading, vocabulary, working memory, and reading comprehension can be found in Table 1. The grades did not significantly differ with respect to working memory, vocabulary, or reading comprehension. There was a significant difference, however, between the groups on sight word efficiency, with significantly higher standard scores in grade 2 than in grades 5 and 6, ($p < 0.01$).

Table 1

*Means (standard deviations) for age, sex, and standardized measures for each grade.*

| | Grade 2 | Grade 3 | Grade 4 | Grade 5 | Grade 6 |
|---|---|---|---|---|---|
| N | 15 | 15 | 15 | 15 | 13 |
| Sex (male/female) | 7/8 | 8/7 | 7/8 | 8/7 | 6/7 |
| Age | $7.13_{a}$ (0.35) | $8.13_{b}$ (0.35) | $9.07_{c}$ (0.26) | $10.13_{d}$ (0.35) | $10.92_{e}$ (0.28) |
| TOWRE-SWE | $116.13_{a}$ (7.77) | $106.13_{a,b}$ (9.82) | $108.47_{a,b}$ (9.36) | $98.93_{b}$ (11.31) | $100.08_{b}$ (11.62) |
| WJIII-PV | $106.60_{a}$ (6.74) | $105.53_{a}$ (8.76) | $105.13_{a}$ (8.18) | $102.87_{a}$ (11.14) | $103.77_{a}$ (9.67) |
| WJIII- AWM | $117.67_{a}$ (6.79) | $109.73_{a}$ (13.37) | $114.67_{a}$ (14.5) | $112.1_{a}$ (11.3) | $108.3_{a}$ (9.48) |
| TORC3-PR | $10.07_{a}$ (1.03) | $10.0_{a}$ (1.41) | $10.20_{a}$ (1.90) | $10.0_{a}$ (1.81) | $9.31_{a}$ (1.37) |

*Notes.* Means in the same row that do not share subscripts differ at $p < 0.01$ in the Bonferroni Pairwise Comparisons. Age = Chronological age (years); TOWRE-SWE = Standard score from Test of Word Reading Efficiency, Sight Word Efficiency Subtest; WJIII-PV = Standard score from the Woodcock Johnson Test of Achievement, Third Edition, Picture Vocabulary Subtest; WJIII-AWM = Standard score from the Woodcock Johnson Test of Achievement, Third Edition, Auditory Working Memory subtest; TORC3-PR = Scaled score from the Test of Reading Comprehension, Third Edition, Paragraph Reading Subtest.

*Illustrations and Bridging Inferences: Developmental Findings*

To test the effects of grade and illustrations on bridging inference accuracy, a 5 group (grades two to six) by 3 illustration condition (activation, suppression, text only) mixed ANOVA was completed (means are in Table 2). The raw scores from the TOWRE was entered as a covariate to remove any variability in the results that might be accounted for by fluent and accurate word decoding.

Table 2

*Mean number of Correct Inferences Made in Each Condition by Grade.*

| Grade | Activation *M (SD)* | Text Only *M (SD)* | Suppression *M (SD)* |
|---|---|---|---|
| 2 | 4.27 (1.16) | 2.80 (1.08) | 1.80 (0.68) |
| 3 | 4.53 (1.25) | 2.87 (1.18) | 2.33 (1.05) |
| 4 | 5.53 (1.25) | 4.27 (1.34) | 3.53 (1.13) |
| 5 | 5.40 (1.30) | 4.67 (1.18) | 4.07 (1.53) |
| 6 | 5.54 (0.88) | 5.00 (1.47) | 4.85 (0.99) |

*Note*. Each mean is the total number of correct inferences made out of a possible eight.

This analysis revealed a main effect of grade, $F(4, 67) = 10.61, p < 0.01$ and a main effect of condition, $F(2, 134) = 9.11, p < 0.01$. These effects were qualified by a significant interaction, $F(8, 134) = 3.16, p < 0.05$. A series of paired sample t-tests were completed to compare the number of correct inferences made between each condition per grade. A Bonferroni correction was applied to control for the number of t-tests completed, which set the alpha to 0.003. The results from these analyses indicated that the number of correct inferences made in the activation condition was significantly higher than in the suppression condition for grades two to five and there was a trend toward this effect for grade six, $p = 0.006$. The number of correct inferences made in the activation condition was significantly higher than in the text-only condition for grades two to four but not for grades give and six. Finally, the difference in accuracy scores between the text-only and suppression condition was only significant for grade two (see Appendix A for results from Pairwise Comparisons).

*Illustrations and Incorrect Choice of Continuation Sentence*

Recall that there were three answer choices for each item, one reflecting that the correct inference had been made and two that were considered incorrect. Of the two choices considered to be incorrect, one reflected a choice that was incompatible with the model activated by the statement sentence, but that was consistent with the intervening sentences in the story that had created a conflicting model. This choice indicated a lack of suppression. The second incorrect choice continued the story with information that was neutral with respect to both of the situation models described by the statement sentence and the intervening sentences. Thus, for each item, the participant could either make the correct inference, or select one of two types of incorrect choices, herein discussed as the *lack of suppression* choice and the *neutral* choice.

To more closely examine the effect of illustrations on bridging inferences, an analysis was completed to determine if the illustrations influenced which type of incorrect choice was selected. A 5 (grade) by 3 (condition) by 2 (incorrect choice type – lack of suppression versus neutral) mixed ANOVA was completed (see table 3 for means). There was a main effect of grade $F(4, 68) = 14.30$, $p < 0.01$, such that the total number of incorrect inferences decreased with grade. There were also main effects of condition and of incorrect choice type ($F(2, 136) = 70.76$, $p < 0.01$; $F(1, 68) = 79.71$, $p$

< 0.01, respectively) that were qualified by a significant interaction, $F(2, 136) = 6.94$, $p < 0.01$. After applying a Bonferroni correction, pairwise comparisons revealed that the most commonly made incorrect choice was the one that reflected a lack of suppression *when* that item was represented in the suppression illustration condition.

Table 3

*Mean Number of Incorrect Choice Type per Condition*

| | Type of Incorrect Choice | |
|---|---|---|
| Condition | Lack of Suppression *M (SD)* | Neutral *M (SD)* |
| Suppression | $3.08_{a}$ *(1.19)* | $1.63_{c}$ *(0.97)* |
| Text Only | $2.29_{b}$ *(1.24)* | $1.82_{b,c}$ *(1.12)* |
| Activation | $1.90_{b,c}$ *(1.03)* | $1.07_{d}$ *(0.81)* |

*Note*. Means that do not share subscripts differ at $p < 0.003$

Referring back to the example provided in figure one, this would be choosing the sentence "Tim asked for a big piece of cake" when the accompanying picture showed the mother serving the birthday cake. The least frequent incorrect choice type was choosing the neutral sentence in the activation illustration condition, that is "Tim asked for the balloon animal" when the accompanying picture showed the boy with a full stomach. The only other pairwise comparison for which there was a significant difference was that more 'lack of suppression' incorrect choices were made in the text only condition than neutral incorrect choices were made in the suppression condition; there were no significant differences between any of the other incorrect inference types within conditions (see Appendix B for results from pairwise comparisons).

*Illustrations and Bridging Inferences: The Role of Working Memory*

To test the hypothesis that the illustrations would have a differential effect on the relationship between working memory and inferencing ability, hierarchical multiple regressions were conducted to determine whether working memory accounted for any additional variance in inferencing ability over and above age, word reading skill, and vocabulary knowledge. A total of four regressions were completed to determine if there were differences in how working memory related to inferencing ability based on illustration condition. They were on the total number of correct inferences made (collapsing across conditions) as well as on the number of correct inferences made within each condition separately (activation, text-only, suppression). In each regression, age was entered first to control for age effects, as the BRIDGE-IT Picture Version task is not standardized for age. Word reading skill and vocabulary knowledge were entered second because research has consistently demonstrated that they are reliable predictors of inferencing as well as reading comprehension in general. The measure of working memory was entered last.

The regression on the total number of inferences made predicted 63% of the variance (Step 1, age, $R^2 = 0.39, p < 0.01$; Step 2, word reading and vocabulary knowledge, $\Delta R^2$=0.060, $p < 0.05$; Step 3, working memory, $\Delta R^2$=0.18, $p < 0.01$). The regression on the items in the activation condition predicted 33% of the variance (Step 1, age, $R^2 = 0.128, p < 0.05$; Step 2, word reading and vocabulary knowledge, $\Delta R^2$=0.032, *ns*; Step 3, working memory, $\Delta R^2$=0.172, $p < 0.01$). The regression on the items in the text-only condition predicted 56% of the variance (Step 1, age, $R^2 = 0.353, p < 0.01$; Step 2, word reading and vocabulary knowledge, $\Delta R^2$=0.069, $p < 0.05$; Step 3, working memory, $\Delta R^2$=0.143, $p < 0.01$). The regression on the items in the suppression condition predicted 64% of the variance (Step 1, age, $R^2 = 0.437$, $p < 0.01$; Step 2, word reading and vocabulary knowledge, $\Delta R^2$=0.061, $p < 0.01$; Step 3, working memory, $\Delta R^2$=0.147, $p < 0.01$). Thus, working memory was a significant and unique predictor of inferencing ability in all four hierarchical regressions when age, word reading skill, and vocabulary knowledge were controlled (see Appendix C).

### *Bridging Inferences and Reading Comprehension*

Finally, a hierarchical regression was conducted to investigate the relationship between the experimental task and the standardized measure of reading comprehension included in this study. Word reading and vocabulary measures were entered first and total inferencing ability from the BRIDGE-IT was entered second in a hierarchical regression of the standardized measure of reading comprehension, the TORC3-PR. The regression predicted 27% of the variance (Step 1, word reading and vocabulary knowledge, $R^2$ = 0.036, *ns*; Step 2, total number of correct inferences on the BRIDGE-IT Picture version, $\Delta R^2$=0.233, $p < 0.01$; see Appendix D)

## Discussion

Conclusions regarding the role that illustrations have in children's reading comprehension have previously been drawn from studies measuring literal comprehension and factual recall. However, current models of reading comprehension emphasize the importance of more complex processes and higher-order skills, such as mental model development through such processes as inference making. The effect of illustrations on these processes has never been examined. The primary goal of the current study was to determine if illustrations affect children's ability to make bridging inferences during reading, and if so, to examine the nature of that effect. Results suggest that as they read, younger children integrate information from accompanying illustrations into their developing mental model of the text, and that they make inferences based on this model. The main findings from the present study were that (1) illustrations that represented the information that was important to keep activated to make the inference had a facilitative effect and illustrations that represented the conflicting information for making the inference had an interfering effect, but that this effect was reduced as grade increased; (2) the role of working memory in predicting inferencing ability was not differentially affected by the illustrations, but was a unique and significant predictor of inferencing in all three conditions and (3) inferencing ability as measured by the experimental task designed for the present study was a significant predictor of performance on the standardized measure of reading comprehension.

### *Illustrations and Inferencing Ability: Developmental Differences*

The findings from the current study suggest that illustrations are one of the contextual cues that children rely on to decide which information is relevant to be integrated into their mental model (Kintsch, 1992). Participants were most accurate at bridging inferences when a picture was included with the text that represented the relevant model for making the inference (the 'activation' condition) and were the least accurate when the illustration was related to the intervening portion of the text (the 'suppression' condition). Furthermore, the most commonly made error across ages was selecting the sentence that was related to the conflicting model, when this portion of the text was represented in picture format. Taken together, these findings suggest that illustrations are a salient cue that children process and integrate into their mental representation of the text.

The results of the current study also demonstrate that the extent of this effect depends on the age of the child. The effect of illustrations on bridging inferences appears to gradually diminish as children move into higher grade levels. Specifically, for the youngest children (grade twos) there were differences in inferencing ability between all three conditions. Moving into grades three and four, the differences between the suppression and the text-only conditions disappeared. By the time children reached grade five, there were no differences between the text-only and the activation condition, and then by grade six there was only a trend toward differences between the two experimental conditions. These results clearly indicate a gradual lessening of the effect of illustrations as grade increased.

Depending on what information was depicted, the effect of the illustrations was either facilitative or interfering. When compared to text with no accompanying illustrations, the facilitative effect of the illustrations supporting the relevant mental model in the text was present until grade four. Conversely, the interfering effect of the illustrations that depicted the conflicting mental model was only evident for children in grade two. By grade five, this effect was reduced in that differences were no longer present between either of the two experimental conditions and the control condition, although it is apparent that the illustrations were still having some effect on bridging inferences for the older children, as they made more correct inferences in the activation condition than in the suppression condition. Thus, it appears that illustrations are a more powerful cue for younger readers than older readers. Goldstein and Underwood (1981), in their review of studies of illustrations and comprehension, also concluded that younger and less skilled readers are more influenced by illustrations. Donald (1983) found that the effect of illustrations is much stronger for younger readers (age seven) than older (age nine). Perhaps older children are less influenced by illustrations because they have stronger skills in decoding, vocabulary and grammatical knowledge, and other cognitive and language skills that are important for reading and reading comprehension. Conceivably, younger children who have not yet consolidated all of the necessary skills required for gaining meaning from the text may rely more on the information contained in the illustrations to make inferences.

Although researchers generally agree that illustrations affect reading, especially in younger readers, contention exists in the literature regarding whether the effect is helpful (e.g., Brookshire et al., 2002; Donald, 1979) or harmful (e.g., Samuels, 1970; Willows, 1978). With regard to children's inferential comprehension, the findings from the current study provide support for both sides of this broader debate. Specifically, illustrations were found to improve children's inferencing ability when they represented the information that had to remain activated in order to build an accurate mental model of the situation described by the text. However, illustrations interfered with this ability when they represented the information from the conflicting model. Peeck (1974) demonstrated a similar effect when she had grade four children read stories with pictures that were either congruent or incongruent with the content of the text. She found that children answered more questions correctly when the text was presented with a congruent picture than when the text was presented alone. Furthermore, she found that when answering questions about information that was presented incongruently, the children were more likely to answer based on the information from the picture than the text (Peeck, 1974). This finding and the results of the current study suggest that the effect of pictures on reading comprehension depends on how representative the picture is of the text and to what extent it corresponds with the intended meaning (Goldstein & Underwood, 1981). In other words, the effect of pictures on inferencing is dependent on the relevance of the information depicted.

Interestingly, in the current study, the interfering effect of the illustrations when compared to the control or text-only condition was no longer present after grade two. This suggests that perhaps the suppression mechanism that Gernsbacher (1990) would purport is central to mental model building during comprehension becomes more efficient in the later primary grades. A clear model of the development of reading comprehension does not exist and there are no studies that have directly explored the development of the suppression mechanism. However, the ability to suppress irrelevant information is thought be part of the family of broader inhibitory processes (Harnishfeger, 1995), and more is known about the development of these processes than is known about the development of suppression processes in comprehension per se.

Inhibitory processes become more efficient with age (e.g., Bjorklund & Harnishfeger, 1990; Dempster, 1993). Inhibition is thought to enhance task performance by keeping information that is irrelevant to the task from entering and being maintained in working memory (Harnishfeger, 1995). Harnishfeger and Bjorklund (1993) reported a series of experiments where they explored children's ability to inhibit irrelevant information during cognitive processing by measuring their intrusion errors in a memory task. They found that preschool and kindergarten children made more intrusion errors than did children in grades three and six. They concluded that young children's inhibitory mechanisms are not well developed, which results in less efficient cognitive processing because it causes their limited working memory to be filled with irrelevant information (Harnishfeger & Bjorklund, 1993). The current findings support Harnishfeger and Bjorklund's (1993) conclusions and extend them to reading comprehension by indicating that the mechanism responsible for suppressing irrelevant information becomes more efficient with age, as the illustrations had less of an interfering effect on inferencing ability after grade two.

*Illustrations and Inferencing Ability: Individual Differences*

A substantial amount of research has demonstrated the facilitative effect of pictures on recall and literal comprehension (e.g., McDaniel & Waddill, 1994; Peeck, 1994). These findings are typically explained through the beneficial effect of illustrations on memory. Most commonly, Paivio's (1986) dual-code theory is used to explain these findings in that information is easier to recall when it is encoded in two forms (i.e., picture and text format). It has also been suggested that illustrations serve to reduce the demands on working memory, thus freeing up more resources for higher-order processing of the text (Levin and Mayer, 1993; Marcus et al., 1996). Based on this notion, it was predicted in the present study that the illustrations would differentially affect the relationship between working memory and inferencing ability. This hypothesis, however, was not supported. Working memory ability was a significant and unique predictor of inferencing ability in all three illustration conditions

The working memory task employed in the current study involved the storage and manipulation of verbal information. It did not, however, provide a measure of intrusion errors. DeBeni and Palladino (2000) suggested that intrusion errors in working memory tasks, such as the one used by Harnishfeger and Bjorklund (1993), are due to inefficient suppression. They included a similar task in a study of children's reading comprehension and found that the poor comprehenders made more intrusion errors and recalled more irrelevant information from the text. Comprehension is thought to be affected by the inability to suppress because it causes working memory to become overloaded with information that is irrelevant to the task at hand (e.g., Palladino, Cornoldi, DeBeni, & Passaglia, 2001). Working memory is also important for updating as readers progress through the text. As new information is read, the mental model is continually updated so that the information that remains activated is relevant to the unfolding situation described by the text (Kintsch, 1988). The updating of the model involves the reactivation of information from previous cycles and subsequent integration of that information with the material in working memory (Barnes, Huber, Johnston, & Dennis, 2007).

In sum, there are certain aspects of working memory that are purported to be important for reading comprehension that were not measured by the task used in the current study. It may be that individual differences in these aspects of working memory (e.g., suppression, updating, reactivation) would have different value in predicting inferencing depending the type of accompanying illustration. For instance, one might expect that the predictive value of the ability to suppress information would be more influenced by pictures, because children who have difficulty inhibiting irrelevant information from entering working memory may be more likely to utilize the information from the pictures as a basis for drawing inferences.

Despite the fact that working memory did not influence the effect of the illustrations, it was a significant predictor of the ability to make bridging inferences. Even after age, word reading skill, and vocabulary knowledge were entered into the model, working memory accounted for a significant amount of the variance in inferential comprehension. Researchers have argued that working memory capacity is causally related to reading comprehension because it is thought to be the workspace where the processes of integration and inferencing take place (Cain et al., 2004). Research has consistently demonstrated the relationship between working memory and reading comprehension (see Cain, 2006), and working memory has been found to be impaired in groups of poor comprehenders (see Swanson, Howard, & Sáez, 2007). Even so, there has been very little work done with children that has specifically examined the contribution made by working memory to some of the component skills of reading comprehension, such as bridging inferences.

The results from the current study strongly suggest that working memory is predictive of bridging inferencing ability, though aspects of the particular inferencing task used may have put especially high demands on working memory resources. For instance, on this task the statement sentence (i.e., the sentence that had to be integrated with one of the multiple choice alternatives to make the correct inference) was always the first sentence in the story and it was separated from the multiple choice answers by intervening text. Previous research on bridging inferences has manipulated the length of the dividing text, ranging from zero to three sentences (Johnston et al., 2006), and has found that the ability to make bridging inferences is negatively affected by the increasing distance. Other work has shown that poor comprehenders' ability to infer the meaning of novel words is also negatively affected by the length of intervening text (Cain et al., 2004). In the current study the length of the intervening text was even longer than in previous work (four sentences). Requiring children to hold the first sentence in memory across four sentences in addition to preventing them from re-reading the story after viewing the multiple choice answers, may explain why working memory was such a strong predictor of inferencing ability in the current study. This aspect of the task also has implications for the effect that illustrations may have during listening comprehension. Specifically, when children are listening to stories they are not able to reread the text. Perhaps illustrations are especially important when children are not able to return to the text to clarify any aspects they are unsure about, due to their saliency.

*Bridging Inferences and Reading Comprehension*

A final important finding from this study was that the experimental measure designed for the study, the BRIDGE-IT picture version, was a strong and unique predictor of performance on the standardized measure of reading comprehension, the TORC3-PR. In addition to providing further evidence that inferencing ability is an important component skill of reading comprehension (Cain et al., 2004), it also strengthens the conclusions made about illustrations and reading comprehension in the current study. The fact that performance on the experimental task predicted performance on the standardized task is an indication of the validity of the BRIDGE-IT picture version. Furthermore, developmental differences in inferencing ability emerged even though word reading skill was entered as a covariate into the model. This provides further support for theoretical models of reading comprehension that highlight the importance of higher-order skills, such as inferencing ability, in reading comprehension.

*Limitations and Future Directions*

There are limitations that should be considered when interpreting the results from the current study. As discussed above, the working memory task employed did not include measures of the ability to suppress, reactivate, or update information. Individual differences in these areas may affect the influence of illustrations on bridging inferences.

There are also some characteristics of the sample that may limit the generalizability of the findings, namely with regard to word reading and working memory. Specifically, the sample of grade twos had exceptionally high word reading ability, which may not be representative of a typical grade two sample. In addition the participants in the current study had above average working memory abilities ($79^{th}$ percentile). As there were very few participants in the current sample who would be considered to have low verbal working memory ability, it might be that illustrations do affect the association between working memory and inferential comprehension, but that the current study was not able to detect it due to a lack of participants who had actual working memory difficulties. Perhaps research with a sample of children that includes those with significant working memory problems would reveal such an effect.

Recent findings suggest that children have more difficulty making bridging inferences when the statement sentence contains affective information than when it contains concrete information (Johnston, Barnes, & Desrochers, 2008). A small number of items from the bridging inferences task employed in the current study required the child to make inferences about affective information (e.g., the girl is scared of sharks so she cautiously entered the water), however it was not a large enough number to determine if the role of illustrations in inferencing skill is different when integrating affective rather than concrete information (e.g., it was raining outside so the family could not light a fire). In addition, although the ability to make bridging inferences involves the integration of two pieces of information that are explicitly stated in the text, the reader inevitably must rely on some basic world knowledge to make the connections (such as you cannot light a fire if it is raining). Although the amount of background knowledge required to make the inferences in the current study is considered minimal, it does have the potential to limit the child's ability to make inferences, and children in the current study were not tested for general knowledge.

There are several other potentially important variables that were not addressed by the current study, such as: how much time and attention children of different ages and skill levels are devoting to looking at the pictures; if there is an effect of when the picture is presented (e.g., before or after the text); or if the amount of time children take to read the text differs depending on if there is a picture present or the characteristics of the picture. Perhaps the most pressing question that emerges from the current findings, is does the effect of illustrations on inferential comprehension differ for good and poor comprehenders? Future studies should examine the effect of illustrations on children with a wider range of abilities, namely in working memory and comprehension. Based on the results from the present study it would be expected that the poor comprehenders might be more affected by illustrations than good comprehenders; if children are unable to understand the information in the text, they may rely on the information from the pictures to guide their understanding.

*Conclusions*

The results from the present study support the hypothesis that children integrate information from illustrations into their mental representation of the text during reading comprehension (Gyselinck & Tardieu, 1999). The current findings suggest that pictures are one of the cues children utilize to determine which information is important to keep activated in the mental model, but that younger readers rely more on pictures for inference making than older readers. This can be beneficial when the information in the picture is required for making the inference, but harmful if it is not. The current study also supports previous work that has found that the ability to make inferences increases with age and is an important component skill of reading comprehension. Contrary to predictions, working memory was important for making inferences regardless of the type of illustration or the presence of illustrations.

In sum, the current study implicates illustrations as a salient source of information that children process in conjunction with the text and suggests that the ability to make bridging inferences is affected by their presence. It also adds to the growing body of literature concerned with the skills important for reading comprehension as well as the development of these skills. In particular, the findings implicate aspects of inhibitory control as being important for comprehension, particularly in younger comprehenders, warranting further exploration of this relationship in the future.

References

Ackerman, B.P. (1988). Reason inferences in the story comprehension of children and adults. *Child Development, 59*, 1426-1442.

Barnes, M.A. & Dennis, M. (2001). Knowledge-based inferencing after childhood head injury. *Brain and Language, 76,* 253-265.

Barnes, M.A., Faulkner, H., Wilkinson, M., & Dennis, M. (2004). Meaning construction and integration in children with hydrocephalus. *Brain and Language, 89*, 47-56.

Barnes, M.A., Huber, J., Johnston, A., & Dennis, M. (2007). A model of comprehension in spina bifida meningomyelocele: Meaning activation, integration, and revision. *Journal of the International Neuropsychological Society, 13,* 854-864.

Barnes, M.A., Johnston, A. & Dennis, M. (2007). Comprehension in a neurodevelopmental disorder, Spina Bifida Myelomeningocele. In K. Cain and J. Oakhill (Eds.) Children's Comprehension Problems in Oral and Written Language, (pp. 193-217). New York, NY: The Guilford Press

Bjorklund, D.F., & Harnishfeger, K.K. (1990). The resources construct in cognitive development: Diverse sources of evidence and a theory of inefficient inhibition. *Developmental Review, 10,* 48-71.

Brookshire, J., Scharff, L.F., & Moses, L.E. (2002). The influence of illustrations on children's book preferences and comprehension. *Reading Psychology, 23,* 323-339.

Brown, V., Hammill, D.D., & Wiederholt, J.L. (1995). *Test of Reading Comprehension (3rd ed.).* Austin, TX: PRO-ED.

Cain, K. (2006a). Individual differences in children's memory and reading comprehension: An investigation of semantic and inhibitory deficits. *Memory, 14,* 553-569.

Cain, K. (2006b). Children's reading comprehension: The role of working memory in normal and impaired development. In S. Pickering (Ed.), *Working Memory and education* (pp. 62-91). San Diego: Academic Press.

Cain, K. & Oakhill, J. (1999). Inference making and its relation to comprehension failure. *Reading and Writing, 11*, 489-503.

Cain, K. & Oakhill, J. (Eds.) (2007). *Children's Comprehension Problems in Oral and Written Language,* New York, NY: The Guilford Press

Cain, K., Oakhill, J., & Bryant, P. (2004). Children's reading comprehension ability: Concurrent prediction by working memory, verbal ability, and component skills. *Journal of Educational Psychology, 96*(1), 31-42.

Cain, K., Oakhill, J., & Elbro, C. (2003). The ability to learn new word meanings from context by school-age children with and without language comprehension difficulties. *Journal of Child and Language, 30*, 681-694.

Cain, K., Oakhill, J., & Lemmon, K. (2004). Individual differences in the inference of word meanings from context: The influence of reading comprehension, vocabulary knowledge, and memory capacity. *Journal of Educational Psychology, 96,* 671-681.

Castell, M. A., & Simpson, G. B. (1991). Textual coherence and the development of inferential generation skills. *Journal of Research in Reading, 14*(2), 116-129.

Davis, B., Johnston, A. M., & Barnes, M. A. (2006). *The Bridging Inferences Task.* Unpublished test, University of Guelph.

Davis, B. J., Johnston, A. M., Barnes, M.A., & Desroches, A. (2007). Bridging inferences in children from grades three to eight. *Poster presented at Canadian Psychological Association's Annual Convention,* Ottawa, Ontario.

DeBeni, R. & Palladino, P. (2000). Intrusion errors in working memory tasks. Are they related to reading comprehension ability? *Learning and Individual Differences, 12,* 131-143.

Dempster, F.N. (1993). Resistance to interference: Developmental changes in a basic processing mechanism. In M.L. Howe & R. Pasnak (Eds.), *Emerging themes in cognitive development: Vol. 1. Foundations* (pp. 3-27). New York: Springer-Verlag.

Donald, D.R. (1983). The use and value of illustrations as contextual information for readers at different progress and developmental levels. *British Journal of Educational Psychology, 53,* 175-185.

Donald, D.R. (1979). Effects of Illustrations on Early Oral Reading Accuracy, Strategies and Comprehension. *British Journal of Educational Psychology, 49,* 282-289

Ehri, L.C., Deffner, N.D., & Wilce, L.S. (1984). Pictorial mnemonics for phonics. *Journal of Educational Psychology, 76,* 880-893.

Evans, M.A. & Saint-Aubin, J. (2005). What children are looking at during shared storybook reading: Evidence from eye movement monitoring. *Psychological Science, 16,* 913-920.

Gernsbacher, M. A. (1990). *Language comprehension as structure building.* Hillsdale, NJ, England: Lawrence Erlbaum Associates

Gernsbacher, M.A. (1993). Less skilled readers have less efficient suppression mechanisms. Psychological Science, 4, 294-298.

Gernsbacher, M.A. (1997). Coherence cues mapping during comprehension. In J. Costermans & M. Fayol (Eds.), *Processing interclausal relationships: Studies in the production and comprehension of text* (pp. 3–21). Mahwah, NJ: Erlbaum.

Gernsbacher, M.A. & Faust, M.E. (1991). The mechanism of suppression: A component of general comprehension skill. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 17,* 245-262.

Glenberg, A.M. & Langston, W.E. (1992). Comprehension of illustrated text: Pictures help to build mental models. *Journal of Memory and Language, 31,* 129-151.

Goldstein, R. & Underwood, G. (1981). The influence of pictures on the derivation of meaning from children's reading materials. *Journal of Research in Reading, 4,* 6-16.

Gyselinck, V., & Tardieu, H. (1999). The role of illustrations in text comprehension: What, when, for whom, and why? In H. van Oostendorp & S.R. Goldman (Eds). The *Construction of Mental Representations During Reading* (pp. 195-218). Lawrence Erlbaum Associates, Mahwah, NJ.

Haring, M.J., & Fry, M.A. (1979). Effect of pictures on children's comprehension of written text. *Educational Communication and Technology Journal, 27,* 185-190.

Harnishfeger, K.K. (1995). The development of cognitive inhibition: Theories, Definitions, and Research Evidence. In F.N. Dempster & C.J. Brainerd (Eds.) *Interference and Inhibition in Cognition* (pp. 176-199). San Diego: Academic Press.

Harnishfeger, K.K., & Bjorklund, D.F. (1993). The ontogeny of inhibition mechanisms: A Renewed approach to cognitive development. In M.L. Howe & R. Pasnak (Eds.), *Emerging themes in cognitive development: Vol. 1. Foundations* (pp. 3-27). New York: Springer-Verlag.

Johnson-Laird, P. N. (1983). *Mental Models: Towards a Cognitive Science of Language, Inference and Consciousness.* Cambridge: Cambridge University Press.

Johnston, A. M. (2006). *The Role of Attentional Control in Reading Comprehension.* Unpublished masters thesis, University of Guelph, Guelph, Ontario, Canada.

Johnston, A.M, Barnes, M.A., Davis, B.J., & Desrochers, A. (2006). The Role of Attentional Control in Inferential Comprehension. *Poster presented at Canadian Language and Literacy Research Network's Annual Conference,* Charlottetown, Prince Edward Island.

Johnston, A.M., Barnes, M.A., & Desrochers, A. (2008). Bridging Inferences in School Aged Children. *Poster presented at Canadian Psychological Association's Annual Convention,* Halifax, Nova Scotia.

Just, M.A. & Carpenter, P.A. (1992). A capacity theory of comprehension: Individual differences in working memory. *Psychological Review, 99,* 122-149.

Kintch, W. (1988). The role of knowledge in discourse comprehension: A construction integration model. *Psychological Review, 95*, 163-182.

Kintsch, W. (1991). How readers construct situation models for stories: The role of syntactic cues and causal inferences. In A. F. Healy, S. M. Kosslyn, & R. M.

Shiffrin (Eds.), *From learning processes to cognitive processes: Essays in honor of William K. Estes* (vol. *2,* pp. 261-278). Hillsdale, N J Erlbaum.

Kintsch, W. (1992). A cognitive architecture for comprehension. In H.L. Pick, P.W. van den Broek, & D.C. Knill (Eds.). *Cognition: Conceptual and methodological issues* (pp. 143-163). Washington, DC: American Psychological Association.

Kintsch, W. (1994). Text comprehension, memory and learning. *American Psychologist, 49,* 294-303.

Levin, J. R. & Mayer, R. E. (1993). Understanding illustrations in text. In B. K. Britton, A. Woodward, and M. Binkley (Eds.), Learning from textbooks: Theory and practice (pp. 95-119). Hillsdale, NJ: Erlbaum.

Marcus, N., Cooper, M., & Sweller, J. (1996). Understanding instructions. *Journal of Educational Psychology*, *88*, 49-63.

Mather, N., & Woodcock, R.W. (2001). Examiner's Manual. *Woodcock-Johnson III Tests of Cognitive Abilities.* Itasca, IL: Riverside.

McDaniel, M.A., & Waddill, P.J. (1994). The Mnemonic Benefit of Pictures in Test: Selective Enrichment for Differentially Skilled Readers. In W. Schnotz & R.W. Kulhavy (Eds), *Comprehension of Graphics*. (pp. 165-184). Amsterdam, The Netherlands: North Holland.

Moore, P.J. & Skinner, M.J. (1985). The effects of illustrations on children's comprehension of abstract and concrete passages. *Journal of Research in Reading, 8,* 45-56.

Oakhill, J. & Cain, K. (2007). Introduction to comprehension development. In K. Cain & J. Oakhill (Eds.) *Children's Comprehension Problems in Oral and Written Language,* New York, NY: The Guilford Press

Oakhill, J. (1993). Children's difficulties in reading comprehension. Educational *Psychology Review, 5*, 223-237.

O'Keefe, E.J. & Solman, R.T. (1987). The influence of illustrations on children's comprehension of written stories. *Journal of Reading Behaviour, 4,* 353-377.

Paivio, A. (1986). Mental Representations. New York: Oxford University Press

Palladino, P., Cornoldi, C., De Beni, R., & Pazzaglia, F. (2001). Working memory and updating processes in reading comprehension. *Memory and Cognition, 29*, 344 354.

Paris, S.G. & Carter, A. (1973). Semantic and constructive aspects of sentence memory in children. *Developmental Psychology, 9*, 109-113.

Paris, S.G. & Lindauer, B.K. (1976). The role of inference in children's comprehension and memory for sentences. *Cognitive Psychology, 8,* 217-227.

Paris, S.G., Lindauer, B.K. & Cox, G.L. (1977). Discourse comprehension and sources of individual differences. In M.A. Just & P.A. Carpenter (Eds.), Cognitive Processes in Comprehension, (pp. 141-183). Hillsdale, N.J.: Lawrence Erlbaum Associates.

Peeck, J. (1994). Retention of pictorial and verbal content of a text with illustrations. *Journal of Educational Psychology, 66*, 880-888.

Peeck, J. (1987). The role of illustrations in processing and remembering illustrated text. In D.M. Willows & H.A. Houghton (Eds.) The Psychology of Illustration (pp. 115-145). Springer- Verlag: New York.

Peeck, J. (1994). Enhancing graphic-effects in instructional texts: Influencing learning activities. In W. Schnotz, & R. W. Kulhavy (Eds.), *Comprehension of graphics: Advances in psychology* (pp. 291–301). Amsterdam, Netherlands: North-Holland/Elsevier Science.

Samuels, S.J. (1967). Attentional process in reading: the effect of pictures on the acquisition of reading responses. Journal of Educational Psychology, 58, 337-342.

Samuels, S.J. (1970). Effects of pictures on learning to read, comprehension, and attitudes. *Reviews of Educational Research, 40,* 397-407.

Schmidt, C.R. & Paris, S.G. (1983). Children's use of successive clues to generate and monitor inferences. *Child Development, 54*, 742-759.

Schmidt, C.R., Paris, S.G., & Stober, S. (1979). Inferential distance and children's memory for pictorial sequences. *Developmental Psychology, 15*, 395-405.

Swanson, H.L. & Berninger, V. (1995). The role of working memory in skilled and less skilled readers' comprehension. *Intelligence, 21*, 83-108.

Swanson, H.L., Howard, C.B., & Sáez, L. (2007). Reading comprehension and working memory in children with learning disabilities in reading. In Cain, K. & Oakhill, J. (Eds.) (2007). *Children's Comprehension Problems in Oral and Written Language,* (pp.157-190), New York, NY: The Guilford Press

Torgeson, J., Wagner, R., & Rashotte, C. (1999). Test of Word Reading Efficiency. Austin, TX: PRO-ED.

Willows, D.M. (1978). A picture is not always worth a thousand words: Pictures as distractors in reading. *Journal of Educational Psychology, 70,* 255-262.

Woodcock, R. W., McGrew, K. S., & Mather, N. (2001a). *Woodcock-Johnson III.* Itasca, IL: Riverside Publishing

Zwaan, R.A. & Madden, C.J. (2004). Updating Situation Models. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *30,* 283-288.

# Appendix A

Table A1

*Pairwise Comparisons between Mean Number of Inferences Made per Grade*

| Comparison | Grade | df | t | p |
|---|---|---|---|---|
| Activation: Suppression | 2 | 14 | 8.49 | .000* |
| | 3 | 14 | 6.25 | .000* |
| | 4 | 14 | 6.48 | .000* |
| | 5 | 14 | 5.74 | .000* |
| | 6 | 12 | 3.32 | .006 |
| Activation: Text-Only | 2 | 14 | -5.73 | .000* |
| | 3 | 14 | -4.80 | .000* |
| | 4 | 14 | -3.54 | .003* |
| | 5 | 14 | -1.80 | .094 |
| | 6 | 12 | -1.85 | .089 |
| Text-Only: Suppression | 2 | 14 | 4.18 | .001* |
| | 3 | 14 | 1.66 | .120 |
| | 4 | 14 | 2.75 | .016 |
| | 5 | 14 | 1.35 | .199 |
| | 6 | 12 | 0.457 | .656 |

*Note.* Paired Sample t-tests, $p < 0.05$, Bonferroni Corrected, $p' < 0.003$; * = $p < 0.003$

Appendix B

Table B1

*Pairwise Comparisons Between Incorrect Choice Types Within Each Condition*

| Comparison | df | t | P |
|---|---|---|---|
| LoS/S: LoS/A | 72 | 7.84 | .000* |
| LoS/S: LoS/TO | 72 | 4.53 | .000* |
| LoS/S: Neut/S | 72 | 8.07 | .000* |
| LoS/S: Neut/A | 72 | 13.73 | .000* |
| LoS/S: Neut/TO | 72 | 8.27 | .000* |
| LoS/TO: LoS/A | 72 | 2.31 | .024 |
| LoS/TO: Neut/S | 72 | 4.38 | .000* |
| LoS/TO: Neut/TO | 72 | 2.20 | .031 |
| LoS/A: Neut/S | 72 | 1.98 | .051 |
| LoS/A: Neut/TO | 72 | 0.55 | .584 |
| Neut/S: Neut/TO | 72 | -1.27 | .207 |
| Neut/A: LoS/TO | 72 | -7.92 | .000* |
| Neut/A: LoS/A | 72 | -5.44 | .000* |
| Neut/A: Neut/S | 72 | -4.55 | .000* |
| Neut/A: Neut/TO | 72 | -5.42 | .000* |

*Note*. Paired Sample t-tests, $p < 0.05$, Bonferroni Corrected, $p' < 0.003$; * = $p < 0.003$

LoS/S = Choosing the lack of suppression incorrect choice in the suppression condition
LoS/TO = Choosing the lack of suppression incorrect choice in the text-only condition
LoS/A = Choosing the lack of suppression incorrect choice in the activation condition
Neut/S = Choosing the neutral incorrect choice in the suppression condition
Neut/TO = Choosing the neutral incorrect choice in the text-only condition
Neut/A = Choosing the neutral incorrect choice in the activation condition

# Appendix C

Table C1

*Summary of Regression Analysis for Variables Predicting Number of Inferences Made on the BRIDGE-IT Picture Version: Activation Condition*

| Model | | Predictors | B | SEB | ß |
|---|---|---|---|---|---|
| Step 1 | | Age | .027 | .008 | .357* |
| $\Delta R^2$ | .128* | | | | |
| $R^2$ | .128 | | | | |
| Step 2 | | Age | .030 | .010 | .393* |
| | | TOWRE-SWE | .000 | .014 | .003 |
| | | WJ-III-PV | .026 | .016 | .183 |
| $\Delta R^2$ | .032 | | | | |
| $R^2$ | .160 | | | | |
| Step 3 | | Age | .037 | .009 | .484* |
| | | TOWRE-SWE | -.002 | .012 | -.014 |
| | | WJ-III-PV | .033 | .015 | .227* |
| | | WJ-III-AWM | .047 | .011 | .427* |
| $\Delta R^2$ | .172* | | | | |
| $R^2$ | .332 | | | | |

*Note.* * = $p < 0.05$

Table C2

*Summary of Regression Analysis for Variables Predicting Number of Inferences Made on the BRIDGE-IT Picture Version: Text-Only Condition*

| Model | | Predictors | B | SEB | ß |
|---|---|---|---|---|---|
| Step 1 | | Age | .054 | .009 | .0594** |
| $\Delta R^2$ | .353** | | | | |
| $R^2$ | .353 | | | | |
| Step 2 | | Age | .067 | .009 | .736** |
| | | TOWRE-SWE | .034 | .014 | .255* |
| | | WJ-III-PV | .022 | .016 | .127 |
| $\Delta R^2$ | .069* | | | | |
| $R^2$ | .422 | | | | |
| Step 3 | | Age | .074 | .008 | .819** |
| | | TOWRE-SWE | .031 | .012 | .239* |
| | | WJ-III-PV | .029 | .014 | .167* |
| | | WJ-III-AWM | .051 | .011 | .389** |
| $\Delta R^2$ | .143** | | | | |
| $R^2$ | .565 | | | | |

*Note*. * = $p < 0.05$; ** = $p < 0.01$

Table C3

*Summary of Regression Analysis for Variables Predicting Number of Inferences Made on the BRIDGE-IT Picture Version: Suppression Condition*

| Model | | Predictors | B | SEB | ß |
|---|---|---|---|---|---|
| Step 1 | | Age | .061 | .008 | .661** |
| $\Delta R^2$ | .437** | | | | |
| $R^2$ | .437 | | | | |
| Step 2 | | Age | .060 | .009 | .647** |
| | | TOWRE-SWE | -.017 | .013 | -.125 |
| | | WJ-III-PV | .040 | .015 | .230* |
| $\Delta R^2$ | .061* | | | | |
| $R^2$ | .498 | | | | |
| Step 3 | | Age | .067 | .008 | .731** |
| | | TOWRE-SWE | -.019 | .011 | -.141 |
| | | WJ-III-PV | .047 | .013 | .271** |
| | | WJ-III-AWM | .052 | .010 | .395** |
| $\Delta R^2$ | .147** | | | | |
| $R^2$ | .645 | | | | |

*Note.* * = $p < 0.05$; ** = $p < 0.01$

Table C4

*Summary of Regression Analysis for Variables Predicting Total Number of Inferences Made on the BRIDGE-IT Picture Version*

| Model | | Predictors | B | SEB | ß |
|---|---|---|---|---|---|
| Step 1 | | Age | .14 | .021 | .624** |
| $\Delta R^2$ | .390** | | | | |
| $R^2$ | .390 | | | | |
| Step 2 | | Age | .096 | .026 | .426** |
| | | TOWRE-SWE | .040 | .037 | .106 |
| | | WJ-III-PV | .323 | .134 | .265** |
| $\Delta R^2$ | .060* | | | | |
| $R^2$ | .450 | | | | |
| Step 3 | | Age | .038 | .024 | .169 |
| | | TOWRE-SWE | .034 | .030 | .091 |
| | | WJ-III-PV | .388 | .111 | .318** |
| | | WJ-III-AWM | .352 | .060 | .489** |
| $\Delta R^2$ | .18** | | | | |
| $R^2$ | .63 | | | | |

*Note*. * = $p < 0.05$; ** = $p < 0.01$

Appendix D

Table D1

*Summary of Regression Analysis for Variables Predicting Performance on the TORC-PR*

| Model | | Predictors | B | SEB | ß |
|---|---|---|---|---|---|
| Step 1 | | TOWRE-SWE | .017 | .160 | .126 |
| | | WJ-III-PV | .022 | .020 | .129 |
| $\Delta R^2$ | .036 | | | | |
| $R^2$ | .036 | | | | |
| Step 2 | | TOWRE-SWE | .034 | .014 | .254* |
| | | WJ-III-PV | .012 | .018 | .070 |
| | | Total Inferences | .204 | .043 | .502** |
| $\Delta R^2$ | .233** | | | | |
| $R^2$ | .270 | | | | |

*Note.* * = $p < 0.05$; ** = $p < 0.01$