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# The role of illustrations in children's inferential comprehension

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ABSTRACT

Illustrations are a salient source of information in children's books, yet their effect on children's reading comprehension has been studied only through literal factual recall. The purpose of the current study was to determine the effect of illustrations on bridging inferences, an important aspect of meaning making in comprehension models. Identical short stories were presented under different illustration conditions with pictures that represented different parts of the story. Participants were 73 7- to 11-year-olds. Illustrations both facilitated and interfered with inferencing depending on the type of information depicted; however, 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.



## Introduction

Children's books are often accompanied by illustrations that provide an additional source of information that must be processed in conjunction with the text. Illustrations play a prominent role in nearly all of the books that children use to learn to read. During 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). However, very little is known about how illustrations affect reading comprehension. Nearly all of the studies aimed at assessing the influence of illustrations on children's reading comprehension have studied children's literal

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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 (e.g., Brookshire et al., 2002; Haring & Fry, 1979; McDaniel & Waddill, 1994; O'Keefe and Solman, 1987; Peeck, 1994). These studies assessed only the effects of illustrations on children's literal text comprehension and, 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, 2006), 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 inference making and mental model building, which are components identified in cognitive models of comprehension as being important for constructing coherent representations of the text (Gernsbacher, 1990; Kintsch, 1991). It is also important to understand how illustrations interact with cognitive abilities associated with comprehension such as working memory.

Several different theories and cognitive models have been proposed to explain how meaning is constructed during the process of reading comprehension; however, the development of a mental representation of the situation described by the text is an element that is common to all of the major theories (Oakhill & Cain, 2007). Johnson-Laird (1983) called this mental representation a "mental model," explaining that it goes beyond the literal meaning of the text to embody spatial, temporal, causal, motivational, and person- and object-related information. As the reader progresses through the text, the mental model is continuously updated as new information is read and interpreted (Kintsch, 1998; Zwaan & Madden, 2004).

Gernsbacher's (1990) structure building framework hypothesizes that the mental model is constructed from memory nodes that contain all previously comprehended information and become activated by incoming information. If the activated information is relevant for structure building, its level of activation is enhanced. If the activated information is not relevant for ongoing comprehension, suppression of this information occurs (Gernsbacher & Faust, 1991). This frees up memory resources, which then become available for the information activated by subsequent sentences and paragraphs. 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).

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, to develop a coherent understanding (Gernsbacher, 1990; van den Broek, Rapp, & Kendeou, 2005). The making of these connections is referred to as inferencing, which is one of the processes that contribute to the construction of the mental representation of the situation described by the text. The ability to make inferences has been 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 bridging inferences are one type considered as essential for developing and maintaining coherent understanding (Kintsch, 1994). Bridging inferences require the reader to integrate two pieces of explicitly stated information from within the text to maintain coherence.

Developmental studies of inference making have found that this skill increases with age (Casteel & Simpson, 1991). Although young children are able to make some of the same types of inferences as are older children and adults, young children are less likely to do so spontaneously and are more successful when prompted or cued (Barnes, Dennis, & Haefele-Kalvaitis, 1996; Paris & Carter, 1973; Paris & Lindauer, 1976). Consistent and spontaneous making of inferences appears to develop around Grade 3 (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 working memory ability. 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; Cain et al., 2004; Schmidt & Paris, 1983; Schmidt, Paris, & Stober, 1979). Inference making also appears to involve a strong working memory component (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), and limited working memory capacity has consequences for the ability to make inferences (Cain et al., 2004).

Although making inferences is important for constructing meaning during reading, an efficient reader cannot make connections between all of the information that is read or between all prior knowledge that is activated. To determine which information is to remain activated and which information is to be suppressed, the reader relies on contextual cues to determine whether 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 illustrations are one of the cues used by readers, especially young readers, to facilitate the development of the mental model (Glenberg & Langston, 1992; Gyselinck & Tardieu, 1999). Illustrations could act as one of the contextual cues used 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. Thus, it is possible that pictures may facilitate 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, thereby 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 aim 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. A measure of bridging inferences was manipulated to include illustrations under three conditions: consistent, inconsistent, and text-only. The *consistent* condition includes a picture that is related to the information that must remain activated or be reactivated in memory to make the correct inference. In this condition, the accompanying illustration directly supports the correct inference. In the *inconsistent* condition, there is a picture that is related to the information that should be suppressed or ignored to make the correct bridging inference. In this condition, although the illustration bears some relation to the ongoing story, it is representative of a portion of text that is inconsistent with the information necessary to keep activated to make the correct inference. In the *text-only* (i.e., control) condition, there is no picture. If children make more correct inferences in the consistent condition or make more errors in the inconsistent condition, this would suggest that illustrations influence what information remains activated in the mental model, thereby facilitating or interfering with comprehension, respectively.

The first goal of the current study was to determine the effect that type of picture has on bridging inferences and whether this effect depends on the age of the child. Overall, it was predicted that children would make more correct bridging inferences in the consistent condition than in the inconsistent condition and the text-only condition, but because previous research has shown that younger readers are more dependent on contextual support to make inferences than older readers (Ackerman, 1988; Barnes et al., 1996), it was expected that the pictures would influence the inference performance of the younger readers more than the older readers. The first goal of the study was also assessed by analyzing the type of errors that participants made. If, as predicted, children do use information from illustrations when making inferences, in the inconsistent condition there should be a higher frequency of errors that relate to the accompanying illustration.

A second goal of the current study was to determine whether illustrations facilitate comprehension by reducing the processing load in working memory. It was hypothesized that working memory would be a unique predictor of inferencing in the inconsistent condition because the illustration enhances the salience of the competing model, resulting in more information to process and/or suppress. Work-

ing memory was hypothesized to be less important in the consistent condition because the picture supports the inference, thereby reducing the processing demands.

The third goal of the study was to examine the relationship between working memory and bridging inferences with reading comprehension. Although previous work has looked at the relation of these processes to reading comprehension individually, they are rarely studied together in a single sample. Specifically, the third goal was to determine whether bridging inferences account for unique variance in a standardized measure of reading comprehension when working memory is controlled.

## Method

### *Participants*

A total of 73 native English-speaking children ranging from Grades 2 through 6 (7–11 years of age) were recruited from a local school board to participate in the current study. The sample consisted of 36 boys and 37 girls. 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 a major neurological or behavioral disorder (e.g., head injury with hospitalization, autism, conduct disorder), or were being schooled in English as a second language. An additional inclusion criterion was that children needed 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). It was important to ensure adequate word reading and language prerequisite skills for reading comprehension; therefore, participants were excluded if their scores were at least 1 standard deviation below the mean on either of these tests.

Participant characteristics and scores on standardized measures of word reading, vocabulary, working memory, and reading comprehension are reported in Table 1. The grades did not differ significantly with respect to age-standardized scores for 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 ($p < .005$).

### *Materials*

#### *Word reading skill and vocabulary knowledge*

The *Sight Word Efficiency subtest* from the TOWRE (Torgeson et al., 1999) was included as a screener to ensure that the participants had adequate word reading ability.

**Table 1**
Means for age, sex, and standardized measures in each grade.

| | Grade 2 | Grade 3 | Grade 4 | Grade 5 | Grade 6 |
|---|---|---|---|---|---|
| *n* | 15 | 15 | 15 | 15 | 13 |
| Sex (boys/girls) | 7/8 | 8/7 | 7/8 | 8/7 | 6/7 |
| Age (years) | $7.13_a$ | $8.13_b$ | $9.07_c$ | $10.13_d$ | $10.92_e$ |
| | (0.35) | (0.35) | (0.26) | (0.35) | (0.28) |
| TOWRE–SWE | $116.13_a$ | $106.13_{a,b}$ | $108.47_{a,b}$ | $98.93_b$ | $100.08_b$ |
| | (7.77) | (9.82) | (9.36) | (11.31) | (11.62) |
| WJ-III–PV | $106.60_a$ | $105.53_a$ | $105.13_a$ | $102.87_a$ | $103.77_a$ |
| | (6.74) | (8.76) | (8.18) | (11.14) | (9.67) |
| WJ-III–AWM | $117.67_a$ | $109.73_a$ | $114.67_a$ | $112.1_a$ | $108.3_a$ |
| | (6.79) | (13.37) | (14.50) | (11.30) | (9.48) |
| TORC3–PR | $10.07_a$ | $10.00_a$ | $10.20_a$ | $10.00_a$ | $9.31_a$ |
| | (1.03) | (1.41) | (1.90) | (1.81) | (1.37) |

*Note.* Standard deviations are in parentheses. Means in the same row that do not share subscripts differ at $p < .005$ (adjusted Bonferroni alpha value). TOWRE–SWE, standard score from Sight Word Efficiency subtest of the TOWRE; WJ-III–PV, standard score from the Picture Vocabulary subtest of the WJ-III; WJ-III–AWM, standard score from the Auditory Working Memory subtest of the WJ-III; TORC3–PR, scaled score from the Paragraph Reading subtest of the TORC3.

The *Picture Vocabulary subtest* from the WJ-III (Woodcock, McGrew, & Mather, 2001) was included to ensure that the participants had adequate knowledge of word meanings.

*Working memory*

The *Auditory Working Memory subtest* from the WJ-III (Woodcock et al., 2001) was included as the measure of verbal working memory. Each child was asked to listen to a list of words, some of which were digits and some of which 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 became longer as the task progressed. 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.

*Standardized Test of Reading Comprehension*

In the *Paragraph Reading subtest* from the Test of Reading Comprehension, third edition (TORC3–PR) (Brown, Hammill, & Wiederholt, 1995), participants were asked to read a paragraph and answer questions about the paragraph to assess their comprehension (e.g., theme of story, detail recollection, making inferences).

*Bridging inferences measure*

The *Bridging Inferences Test, Picture Version* (*Bridge–IT Picture Version*), was designed to measure the effect of illustrations on the ability to make bridging inferences. It was composed of 24 five-sentence story-like passages. The cover page included detailed directions that were read to each participant. Each story was on a separate page, and the children were instructed to turn the page when they 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 or her own pace.

Each story began with a statement sentence and was followed by four sentences of intervening text. The intervening text contained information that could be seen as conflicting or competing with the first mental model (although it did not interfere with story coherence) 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 promote the development of two competing 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 statement sentence and to suppress or ignore information contained in the following sentences. Each story was presented under one of three conditions: (a) with a picture directly underneath the text representing information from the statement sentence that must remain activated to make the correct inference (the *consistent* condition), (b) with a picture directly underneath the text corresponding to the portion of the text that must be suppressed or ignored to make the correct inference (the *inconsistent* condition), and (c) with no picture at all (the *text-only* or control condition). An example of a story presented under all three conditions can be found in Fig. 1.

Within each booklet of 24 stories, there were 8 stories in each condition presented in alternating order. Three versions of the booklet were created so that each story was presented in each condition, and each version of the booklet was administered an equal number of times within each grade. The illustrations were in color and were purchased from websites.

Each of the three answer choices was designed to assess the children'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 competing mental model; the choice of that answer was presumed to demonstrate a lack of suppression and/or problems in maintaining activation of the statement sentence. The other incorrect alternative was not related to either model and, thus, was considered as neutral. A previous study that employed a nonpicture version of this task reported a reliability coefficient of .73 between parallel versions of the task (Davis, Johnston, Barnes, & Desrochers, 2007).

| Story | Multiple Choice Alternatives |
|---|---|
| John has a broken leg from falling off his skateboard last week.<br>John's friend Andrew invited him to go to his cottage for the weekend.<br>The first day it rained and the boys watched movies inside.<br>The second day it was sunny and Andrew wanted to swim in the lake.<br>The boys loved to jump from the tire swing into the lake. | a) John was the first to jump in from the tire swing and had fun swimming.<br>*b) John played in the sand and watched Andrew play on the tire swing*.<br>c) The boys decided to leave the cottage early to finish their homework. |

| Condition | | |
|---|---|---|
| Consistent | Text-Only | Inconsistent |
|  | NO PICTURE |  |

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

**Fig. 1.** Example of consistent, text-only, and inconsistent 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 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 1 to 2 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 TORC3. The examiner carefully monitored the group-based testing sessions to ensure that instructions were comprehended and that work was done independently.

## Results

### *Illustrations and bridging inferences*

The first goal was to determine the effect that type of picture had on bridging inferences and whether this effect depended on the age of the child. To test the effects of grade and illustrations on bridging inference accuracy, a 5 (Grade: 2, 3, 4, 5, or 6) by 3 (Condition: consistent, inconsistent, or text-only) mixed analysis of variance (ANOVA) was completed. The means are reported in Table 2.

**Table 2**
Mean number of correct inferences made in each condition by grade.

| Grade | Consistent | Text-only | Inconsistent |
|---|---|---|---|
| 2 | 4.27 (1.16)$_a$ | 2.80 (1.08)$_b$ | 1.80 (0.68)$_c$ |
| 3 | 4.53 (1.25)$_a$ | 2.87 (1.18)$_b$ | 2.33 (1.05)$_b$ |
| 4 | 5.53 (1.25)$_a$ | 4.27 (1.34)$_b$ | 3.53 (1.13)$_b$ |
| 5 | 5.40 (1.30)$_a$ | 4.67 (1.18)$_{a,b}$ | 4.07 (1.53)$_b$ |
| 6 | 5.54 (0.88)$_a$ | 5.00 (1.47)$_a$ | 4.85 (0.99)$_a$ |

*Note.* Standard deviations are in parentheses. Each mean is the total number of correct inferences made out of eight possible items. Means in the same row that do not share subscripts differ at $p < .003$ (adjusted Bonferroni alpha value).

The raw scores from the TOWRE were entered as a covariate to remove any variability in the results that might be accounted for by differences between the grades in word reading efficiency.

This analysis revealed a main effect of grade, $F(4, 67) = 10.61$, $p < .01$, $\eta_p^2 = .12$, and a main effect of condition, $F(2, 134) = 9.11$, $p < .01$, $\eta_p^2 = .12$. These effects were qualified by a significant interaction, $F(8, 134) = 3.16$, $p < .05$, $\eta_p^2 = .16$. 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, and this set the alpha to .003. The results from these analyses indicated that the number of correct inferences made in the consistent condition was significantly higher than the number made in the inconsistent condition for Grades 2 to 5 and that there was a trend toward this effect for Grade 6 ($p = .006$). The number of correct inferences made in the consistent condition was significantly higher than the number made in the text-only condition for Grades 2 to 4 but not for Grades 5 and 6. Finally, only the Grade 2 readers had significantly more correct inferences in the text-only condition than in the inconsistent condition.

To provide additional support for the first goal of the study, the relationship between illustrations and inferencing was further explored in an analysis of errors to determine whether the illustrations influenced the type of incorrect choice that was selected. Of the two choices considered to be incorrect, one reflected a choice that was incompatible with the model activated by the statement sentence but was in line with the intervening sentences in the story that were used to create a competing model. This choice indicated a lack of suppression and/or failure to maintain sufficient activation of the model created by the statement sentence. The second incorrect choice continued the story with information that was neutral with respect to both the situation model described by the statement sentence and the intervening sentences. Thus, for each item, the participants could either make the correct inference or select one of two types of incorrect choices, referred to here as the *lack of suppression* choice and the *neutral* choice. Because there were eight items in each condition, the mean number of incorrect choices made in each condition was out of eight possible items.

A 5 (Grade) by 3 (Condition) by 2 (Incorrect Choice Type: lack of suppression or neutral) mixed ANOVA was completed. The means are reported in Table 3. There was a main effect of grade, $F(4, 68) = 14.30$, $p < .01$, $\eta_p^2 = .45$, indicating that the total number of incorrect inferences decreased with grade, paralleling the findings for accuracy. There were also main effects of condition, $F(2, 136) = 70.76$, $p < .01$, $\eta_p^2 = .51$, and of incorrect choice type, $F(1, 68) = 79.71$, $p < .01$, $\eta_p^2 = .54$, that were qualified by a significant interaction, $F(2, 136) = 6.94$, $p < .01$. $\eta_p^2 = .03$. After applying a Bonferroni correction (corrected alpha = .003), pairwise comparisons revealed that the lack of suppression choice in the inconsistent condition was made more often than any other error in any other condition, whereas the neutral choice in the consistent condition was the least commonly made error. The lack of suppression error was made significantly more often than the neutral error in both the inconsistent and consistent conditions, but the two types of error were made with equal frequency in the text-only condition.

### *Illustrations and bridging inferences: The role of working memory*

The second goal of the study was to determine whether illustrations facilitate comprehension by reducing the processing load in working memory. To test the hypothesis that the illustrations would

**Table 3**
Mean number of incorrect choice type per condition.

| Condition | Type of incorrect choice | |
|---|---|---|
| | Lack of suppression | Neutral |
| Inconsistent | $3.08_a$ (1.19) | $1.63_c$ (0.97) |
| Text-only | $2.29_b$ (1.24) | $1.82_{b,c}$ (1.12) |
| Consistent | $1.90_{b,c}$ (1.03) | $1.07_d$ (0.81) |

*Note.* Standard deviations are in parentheses. Means that do not share subscripts differ at $p < .003$ (adjusted Bonferroni alpha value).

have a differential effect on the relationship between working memory and inferencing in the different illustration conditions, hierarchical multiple regressions were conducted to determine whether working memory accounted for any additional variance in inferencing with age, word reading skill, and vocabulary knowledge controlled. Regressions were conducted on the total number of correct inferences made in each condition (consistent, inconsistent, and text-only). In each regression, age was entered first. 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. Because the dependent variable (the Bridge–IT Picture Version) is not a standardized measure, raw scores for word reading, vocabulary knowledge, and working memory were entered into the regression in addition to age.

The regression on the items in the consistent condition predicted 33% of the variance (Step 1, age, $R^2 = .128$, $p < .05$; Step 2, word reading and vocabulary knowledge, $\Delta R^2 = .032$, *ns*; Step 3, working memory, $\Delta R^2 = .172$, $p < .01$). The regression on the items in the text-only condition predicted 56% of the variance (Step 1, age, $R^2 = .353$, $p < .01$; Step 2, word reading and vocabulary knowledge, $\Delta R^2 = .069$, $p < .05$; Step 3, working memory, $\Delta R^2 = .143$, $p < .01$). The regression on the items in the inconsistent condition predicted 64% of the variance (Step 1, age, $R^2 = .437$, $p < .01$; Step 2, word reading and vocabulary knowledge, $\Delta R^2 = .061$, $p < .01$; Step 3, working memory, $\Delta R^2 = .147$, $p < .01$). These results indicate that working memory was a significant and unique predictor of inferencing ability in all conditions (accounting for 14–17% of the variance) when age, word reading skill, and vocabulary knowledge were controlled.

### *Component skills of reading comprehension*

The final goal of the study was to determine whether bridging inferences skill predicted any unique variance in a standardized measure of reading comprehension (TORC3–PR) after working memory was controlled. A hierarchical regression was completed where age was entered first and word reading and vocabulary measures were entered second. Working memory was entered third because working memory has previously been shown to be an important predictor of reading comprehension and because of its relation to bridging inferences in the analyses for the second goal. To determine whether bridging inferences skill would predict any unique variance in reading comprehension, total inferencing ability (the total number of correct inferences made collapsed across conditions) from the Bridge–IT Picture Version was entered last into the hierarchical regression. The regression on the TORC3–PR predicted 75% of the variance (Step 1, age, $R^2 = .47$, $p < .01$; Step 2, word reading and vocabulary knowledge, $R^2 = .03$, *ns*; Step 3, working memory, $\Delta R^2 = .14$, $p < .01$; Step 4, total number of correct inferences made on the Bridge–IT Picture Version, $\Delta R^2 = .11$, $p < .01$) and shows that the ability to make bridging inferences accounted for a significant 11% of unique variance in reading comprehension skill even after other component skills, including working memory, were controlled.

## Discussion

Conclusions regarding the role that illustrations play 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 text-level skills such as the construction of mental models through integrative processes, including inference making. The effect of illustrations on these processes has not been examined previously. The overall aim of the current study was to determine whether illustrations affect children's ability to make bridging inferences during reading and, if so, to examine the extent of that effect.

The main findings from the study are that (a) illustrations that represented the information that was important to keep activated to make the correct inference had a facilitative effect and illustrations that represented competing or conflicting information for making the inference had an interfering effect, but these effects were reduced as grade increased; (b) the role of working memory in predicting inferencing ability in the different conditions was not differentially affected by the illustrations but was a unique and significant predictor of inferencing in all three conditions; and (c) the total number

of inferences made on the experimental task was a unique predictor of performance on a measure of reading comprehension achievement even after other comprehension-related skills, including working memory, were controlled.

*Illustrations and inferencing*

The first goal was to determine the effect that type of picture has on bridging inferences and whether this effect depends on the age of the child. Although researchers generally agree that illustrations affect reading, especially in younger readers, there is disagreement 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 respect to children's inferential comprehension, the findings from the current study provide support for both sides of this broader debate.

The development of a mental model during reading comprehension was described by Kintsch (1988) as a cyclical process whereby incoming information is continually activated and integrated into the existing model. As the reader progresses through the text, the mental model must be updated with new incoming information. Cognitive models of comprehension posit that the reader relies on cues from context to determine which information is important to keep activated within the mental model (Ackerman, 1988; Gernsbacher, 1990; Kintsch, 1991). Results from the current study suggest that illustrations that are representative of the information important for integration facilitate the making of bridging inferences.

To make the correct inferences, the participants were required to connect information contained in the first sentence of the story with the correct multiple-choice alternative. In other words, children needed to keep that information activated in their mental model of the unfolding story or retrieve that information at the point where the inference needed to be made. Children were more accurate at making the inference when the story was presented in conjunction with an illustration that supported the mental model important for making the inference. This finding suggests that illustrations of this type activated or facilitated accessibility of inference-relevant information within the children's mental representation of the situation described by the text.

Children were least accurate at making bridging inferences when the corresponding illustration was related to the information in the text that needed to be suppressed or ignored to make the correct inference. Furthermore, the most common error in this condition was for the children to select the sentence that was consistent with the model in the illustration but inconsistent with the information in the first sentence needed to make the correct inference. Taken together, these findings suggest that illustrations compatible with the unfolding text, but inconsistent with the model of the situation described in the statement sentence, led to sustained activation of a competing mental model, with the consequence that the children were more likely to make an incorrect inference.

*Developmental findings*

An additional component of the first goal was to determine the impact of grade on the findings for illustrations and inferencing. The results suggest that the effect of illustrations on inferencing changes across development. When compared with text with no accompanying illustrations, the facilitative effect of the illustrations supporting the relevant mental model in the text was present until Grade 4. By Grade 5, this effect was reduced in that differences were no longer present between either of the two experimental conditions and the control condition. However, it was also apparent that the illustrations were still having some effect on bridging inferences for the older children because they made more correct inferences in the consistent condition than in the inconsistent condition.

The interfering effect of the illustrations was most apparent for the youngest children in the study (Grade 2), who performed significantly worse in the inconsistent condition when compared with the text-only condition. This suggests that the suppression mechanism purported by Gernsbacher (1990) to be central to mental model building during comprehension may become more efficient in the later primary grades.

A well-specified 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 in reading.

However, the ability to suppress irrelevant information is thought to 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.

Developmental models of cognitive inhibition postulate that although the limited capacity of mental resources available for cognitive tasks and storing information remains constant, the efficiency of the execution of cognitive operations improves across development (Harnishfeger & Pope, 1996). Bjorklund and Harnishfeger (1990) proposed an extension of these models to emphasize the role of inhibitory processes by claiming that increased efficiency in cognitive inhibition directly affects other aspects of cognitive processing such as children's improved memory performance with age. This model posits that young children are not able to suppress the activation of irrelevant information and associations, resulting in less efficient processing because their limited memory capacity is overloaded with irrelevant information (Bjorklund & Harnishfeger, 1990). For example, Harnishfeger and Bjorklund (1993) found that preschoolers and kindergarteners made more intrusion errors on memory tasks than did children in Grades 3 and 6. The current findings support Harnishfeger and Bjorklund's conclusions and extend them to reading comprehension, suggesting that the mechanism responsible for suppressing irrelevant information becomes more efficient with age given that the illustrations had less of an interfering effect on inferencing after Grade 2.

### *Illustrations and working memory*

The second goal of the current study was to determine whether illustrations facilitate comprehension by reducing the processing load in working memory. It has been suggested previously that illustrations serve to reduce the demands on working memory, thereby freeing up more resources for higher order processing of the text (Levin & Mayer, 1993; Marcus et al., 1996). Based on this notion, it was predicted that working memory would be differentially related to making inferences in situations where the illustrations were either consistent or inconsistent with the mental model on which the correct inference relied. This hypothesis, however, was not supported. Working memory ability predicted inferencing in all three conditions (accounting for 14–17% of the variance). To link the statement sentence with the test sentence to make the correct inference, maintenance of activation or reactivation of the appropriate mental model and suppression of the competing mental model were likely required across all three conditions.

Many researchers have described different aspects or subprocesses of working memory (e.g., suppression, updating, reactivation) and have shown that these processes are important for comprehension (DeBeni & Palladino, 2000; Gernsbacher, 1993). The working memory task employed in the current study involved the storage and manipulation of verbal information and did not provide measures of particular aspects of working memory that may be important for reading comprehension in general and for inferencing in particular. Individual differences in these aspects of working memory might have differential value in predicting inferencing depending on the type of accompanying illustration. For instance, it might be expected that the predictive value of the ability to suppress information would be influenced by the type of accompanying illustration. Because pictures are a more salient source of information than text, perhaps children who have difficulty in suppressing irrelevant information from entering working memory would be more likely to use the information from the pictures than from the text as a basis for drawing inferences.

### *Bridging inferences and reading comprehension*

The third and final goal of the current study was to examine the relationship between several of the variables included in this study and a standardized measure of reading comprehension. The finding that the total number of inferences made on the experimental task was a significant predictor of performance on a measure of reading comprehension achievement has implications for the findings on illustrations and inferencing in this study as well as for the literature on reading comprehension more generally. First, the relationship between the experimental task and the standardized task is an indication of the validity of the inferencing measure employed in the current study. In terms of reading comprehension research, the findings from the current study are compatible with those of Cain

et al. (2004), who found that inferencing ability was a significant and unique predictor of reading comprehension in 8- to 11-year-olds after word reading, vocabulary, verbal IQ, and working memory were taken into account. Making inferences is an important part of many models of comprehension, and the current findings provide evidence that the ability to make inferences is an important and unique aspect of reading comprehension even after accounting for working memory.

### *Limitations and future directions*

Some characteristics of the sample may limit the generalizability of the findings, namely with regard to word reading and working memory. Specifically, the sample of children in Grade 2 had high word reading ability, which might not be representative of a typical Grade 2 sample, although this was controlled for in the analyses. In addition, the participants in the current study had above average working memory abilities (79th percentile). Because there were very few participants in the current sample who would be considered as having 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 such a relation due to the restricted range of working memory ability.

There are several important questions that were not addressed by the current study such as the following: (a) how much time and attention children of different ages and skill levels are devoting to looking at the pictures (e.g., Evans & Saint-Aubin, 2005); (b) whether there is an effect of when the picture is presented (e.g., before or after the text); (c) whether the amount of time children take to read the text differs depending on whether there is a picture present or the characteristics of the picture; and (d) whether the effect of illustrations on inferential comprehension differs for good and poor word decoders and for good and poor comprehenders. Finally, although we suggest cognitive mechanisms (e.g., suppression) that might account for some of the effects reported in this article, these hypotheses await further study.

## Conclusions

The findings from the current study support the hypothesis that pictures are salient sources of information that children process in conjunction with the text (Gyselinck & Tardieu, 1999) and that pictures are used in the construction of meaning during reading. However, the findings also suggest that illustrations affect the inference making of younger readers more than older readers. The findings also implicate aspects of inhibitory control as being important for comprehension, particularly in younger comprehenders, warranting further investigation of this relationship in future studies.

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