

# The Effects of Knowledge Availability and Knowledge Accessibility on Coherence and Elaborative Inferencing in Children from Six to Fifteen Years of Age

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Two experiments are presented in which a novel knowledge base was acquired by 6- to 15-year-old children prior to hearing a multiepisode story, and where inferences from the story drew only on that knowledge base. Making knowledge equally available to all children did not attenuate age-related differences in either coherence or elaborative in-

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ferencing. Easily accessible knowledge was generally twice as likely to be used to make inferences during text comprehension as was knowledge that took longer to retrieve, though knowledge accessibility was more important for coherence inferencing in younger than in older children. Children made more coherence than elaborative inferences in the context of text comprehension, even though elaborative inferencing was more frequent in a simpler processing situation. Within the context of an available knowledge base, the results provide evidence for the importance of knowledge accessibility in children's inferencing, and for the changing developmental relevance of knowledge accessibility for coherence and elaborative inferencing. © 1996 Academic Press, Inc.

Comprehending what is heard or read requires the understanding of explicit text elements as well as the elaboration of these elements through integration of information in the text with prior knowledge. Elaborated textual representations correspond to a deeper understanding of the text (Kintsch, 1994) and include knowledge-based inferences, that is, those that integrate text and general knowledge.

Inferencing depends, in large part, on the availability and accessibility of a relevant knowledge base (Morrow, Bower, & Greenspan, 1990; Schneider, Korkel, & Weinert, 1989). While there are age-related changes in both inferencing and general knowledge, little is known about how knowledge availability and accessibility are each related to children's inferencing. The following studies explore two issues important in understanding the development of knowledge-based inferencing: How children of different ages use a circumscribed and available knowledge base to make two types of inferences important for comprehension, and how the accessibility of an available knowledge base is related to inferencing in children of different ages.

## THE ROLE OF THE KNOWLEDGE BASE IN DEVELOPMENTAL AND INDIVIDUAL DIFFERENCES

The knowledge base accounts for individual and developmental differences across a variety of cognitive operations (e.g., Bjorklund & Buchanan, 1989; Keil, 1986; Waggoner & Palermo, 1989). Poor readers (usually shown to have poorer memory than good readers) remember as much as good readers when differences in world knowledge over the two groups are controlled for (Bjorklund and Bernholtz, 1986). Expertise depends more on domain knowledge than on capacity measures such as IQ or short-term memory (Ceci & Liker, 1986; Chase & Simon, 1973; Chi, 1978). For example, child chess experts have better memory for positions of chess pieces than do adult chess novices, despite better performance on measures of short-term memory in the latter (Chi, 1978). And, children with lower IQs make more inferences within an area of their expertise than do children with higher IQs who are naive about the same area (Schneider, Korkel, & Weinert, 1989; Yekovich, Walker, Ogle, & Thompson, 1990).

In the studies described above, the influence of the knowledge base on various cognitive skills has been investigated in two ways. One approach has tailored materials to individual children consistent with their knowledge; here, the *ma-*

*terials* used differ across individuals. The other approach has selected groups differing in their knowledge about a particular domain; here, the *knowledge base* differs across individuals. Studies using preexisting differences in knowledge, however, are sometimes inconsistent with data from those in which knowledge itself is manipulated. For example, teaching new knowledge does not always lead to changes in the cognitive processes (e.g., memory) relying on that knowledge (DeMarie-Dreblow, 1991).

### KNOWLEDGE AVAILABILITY AND KNOWLEDGE ACCESSIBILITY IN INFERENCING

Prior knowledge is critical for inferencing and for text comprehension (Kintsch, 1994). However, while the knowledge needed to make an inference may be available in semantic memory, it may not be equally accessible in all contexts. Information is defined as being available if it is in semantic memory and is retrievable under at least some circumstances. This available information is more or less accessible depending on how quickly it can be retrieved and/or the number of contexts in which it can be retrieved (Glucksberg, Brown, & McGlone, 1993). Less accessible knowledge is less likely to be used during text comprehension because such information takes longer to retrieve; in ongoing text processing, there may be insufficient time to access information slowly and deliberately from semantic memory (Glucksberg et al., 1993). In effect, highly accessible knowledge is more likely to be used to make inferences during text comprehension than is less accessible knowledge.

The accessibility of information that has previously been explicitly presented in a text affects both the probability that an inference will be made with that information and the strength with which an inference is encoded (McKoon & Ratcliff, 1992). This relationship between inferencing and the accessibility of prior text information may also hold for inferencing and the accessibility of knowledge-base information. One hypothesis about children's text comprehension, then, would be that variations in knowledge-base accessibility should be related to differences in constructing inferences using that knowledge.

### KNOWLEDGE ACCESSIBILITY AND THE FUNCTION OF DIFFERENT INFERENCES IN TEXT COMPREHENSION

While the accessibility of knowledge may be related to knowledge-based inferencing in general, it may figure more importantly in the making of some types of inferences than in others. At least two types of inferences are important for understanding a text, one concerned with understanding its propositional text base, the other serving to place the text within a broader mental model that captures the situation described by the text. The inferences that have been studied *vis-a-vis* these roles are coherence inferences and elaborative inferences.

*Coherence inferences* maintain a coherent story line by adding unstated but important information to explicit text. They form a causal link between knowledge and text that helps infer *why* an event occurred. For example, on hearing that

a family ate at home after starting out for a picnic in their car, an inference about the car's implied condition or a sudden change in the weather is important for understanding the events in the story. *Elaborative inferences* embellish story content and amplify its context, even though they are not central to textual cohesion. They specify a fuller description so that *what* an event is like may be inferred. For example, inferring that the sky was a bright blue on hearing "It was a gorgeous sunny day" contributes to the building of a richer mental model of the situation (Johnson-Laird, 1983). Elaborative inferences are thought to strengthen long-term memory for text and, by making concepts more concrete, may facilitate the integration of subsequent propositions (Whitney, Ritchie, & Clark, 1991). Elaborative inferences are claimed to be encoded less often than coherence inferences (Duffy, 1986; Garrod, O'Brien, Morris, & Rayner, 1990; Keenan, Baillet, & Brown, 1984; McKoon & Ratcliff, 1990; review in Whitney, 1987), although their frequency may increase under certain conditions (Morrow, Bower, & Greenspan, 1990).

Given their essential role in text comprehension, coherence inferences may be only minimally affected by knowledge accessibility. When the knowledge needed to make a coherence inference is available but not easily accessible, memory may undergo a more strategic, and exhaustive search until the appropriate information is found. Because elaborative inferences are not necessary for maintaining a minimal level of text comprehension, a factor such as knowledge accessibility may play a greater role in determining which of these inferences are made. Similar types of nonobligatory inferences between explicit concepts in a text have been shown to be made primarily when the previously mentioned concepts are easily accessible (McKoon & Ratcliff, 1992).

Regardless of how knowledge accessibility is related to coherence and to elaborative inferencing, other factors may affect the development of each type of inference (Nicholas & Trabasso, 1980). It is known that both elaborative and coherence inferencing improve with age (Ackerman, 1986, 1988; Johnson & Smith, 1981; Paris & Upton, 1976; Schmidt & Paris, 1983; Zabrocky & Ratner, 1986). Recently, Casteel (1993) demonstrated that children as young as 8 or 9 years of age seem sensitive to causal constraints in a text; they make more inferences that are necessary for comprehension than those that simply elaborate on the text base. However, the two types of inferencing have not been compared in children where inferences are made from the same controlled knowledge base and where the question of interest is how knowledge accessibility affects inferencing.

In the present two experiments, we describe elaborative and coherence inferencing in children from 6 to 15 years of age, where a new knowledge base is taught to all children and where the only inferences required are those that draw on this newly acquired knowledge base. The use of a newly acquired knowledge base also affords the opportunity to investigate how knowledge accessibility, considered apart from knowledge availability, is related to coherence and elaborative inferencing in children of different ages.

## EXPERIMENT 1

## Method

*Subjects*

Fifty-one children (19 boys and 32 girls) between the ages of 6 and 15 years were tested individually. There were nine 6- to 7- year-olds ( $M$  age = 6.78; range = 6.08–7.83); eleven 8- to 9-year-olds ( $M$  age = 8.86; range = 8.0–9.92); eleven 10- to 11-year-olds ( $M$  age = 10.88; range = 10.25–11.92); nine 12- to 13-year-olds ( $M$  age = 12.90; range = 12.0–13.42); and eleven 14- to 15-year-olds ( $M$  age = 14.70; range = 14.25–15.42). Subjects were recruited from five schools in predominantly middle-class neighborhoods, and most placed in the second and third quartiles of the class on the basis of scholastic achievement and reading performance.

*Materials and Procedure*

*Learning the knowledge base.* Knowledge was operationalized as being that which provides the primary inputs to performance of the relevant operation (Yekovich et al., 1990), in this case, inferencing. Characters for an invented world, "Gan," were introduced, and 20 facts about Gan were created by ascribing figmental properties to familiar objects to comprise the controlled knowledge base (e.g., "Turtles on Gan have ice skates attached to their feet," "Bears on Gan have blue fur," and see Appendix). Only the information from this newly created knowledge base was relevant to making the inferences. Thus, the set of 20 items is a knowledge base for Gan in that it constitutes a group of modified concepts that cohere around a topic. The utility of this particular knowledge base for the study of inferencing is that it is readily learned and it can be embedded within a narrative text. The 20 knowledge-base items were read in a block at a rate of 1 item every five seconds.

*Forced-choice picture recognition.* Acquisition of the knowledge base was tested immediately after the items were read, in a procedure whereby the subject had to choose the picture of an item from Gan from among three distractors (true state on Earth, property other than the one ascribed to the object on Gan, and the Ganian property ascribed to another object). The illustrations of the Gan items appeared equally often in each of four positions on the test cards. Figure 1 provides an example of one test card. Subjects were provided with feedback on items that were failed (an incorrect picture choice) by presenting the correct fact before moving on to the next picture test item. After the 20th item had been tested with the pictures, any items that the child failed the first time through were retested with the appropriate pictures. This procedure was repeated until all items had been identified correctly once.

*Presentation of episodes from Gan story.* The Gan story comprised 10 one-paragraph episodes, each with simple grammatical constructions and content vocabulary within the capabilities of an average 6-year-old (Carroll & White, 1973). An example of a Gan episode is found in Table 1. The story was read one

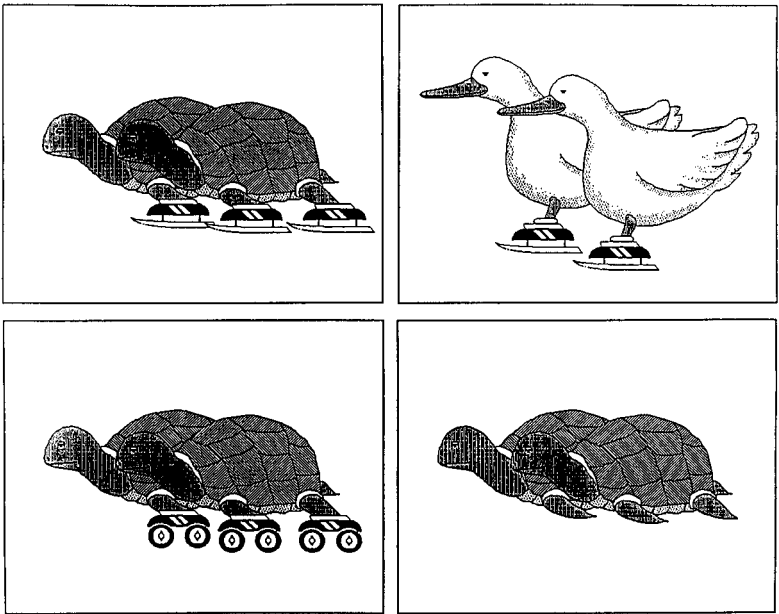


FIG. 1. Forced choice picture recognition card.

episode at a time, after which a 90-s distractor task was administered (reporting on visual illusions), and questions for that episode were asked.

Each episode contained information from which several questions were to be answered (Table 1). A nondirective probe (“Tell me more about that”) obtained

TABLE 1  
Sample Episode from Gan Story

Episode 8:

It was getting so cold that Dack and Tane took their coats out of their bags too. They put on their coats which were made of bear’s fur. It did not take long for the path to become icy and slippery. Dack and Tane kept falling on the ice. They saw two turtles ahead of them on the path. “I sure wish that I was a turtle,” sighed Dack. Tane took a step and fell on top of her knapsack, crushing all the strawberries she had picked earlier that day. When Dack tried to help her up, he fell too. Dack was covered in scrapes and bruises. He was like a boxer who had lost a fight. “Poor Dack,” said Tane as she stood up. “You’ll feel better tomorrow.” She helped Dack up and they walked very carefully along the path, holding each other by the hand.

Elaborative inference question: What did Dack and Tane take out of their bags? (their blue coats, or their blue bear-fur coats)

Coherence inference question: What did Dack wish? (he had ice skates; or he was a turtle because turtles have ice skates; or he was a turtle so he could skate)

Literal question: What happened when Tane fell?

Simile question: What does “Dack was like a boxer who had lost a fight mean?”

more information where required. The information needed to answer each question was counterbalanced across different sentence positions in the episodes.

For the coherence inference, an inference must be made to understand the proposition in question and maintain story coherence (e.g., in the story, the proposition "Dack wished he was a turtle" is anomalous unless it is integrated with a part of the knowledge base, that turtles on Gan have ice skates). For an elaborative inference, a subject who made the inference that the children's coats were blue (the coats were made of bear's fur and the bears on Gan are blue) would add information and create a richer mental content to the proposition "They put on their coats made of bear's fur," even though textual coherence does not require this inference.

Questions about literal content were used to track the subject's understanding of literal text propositions. One might expect that memory for text would be a prerequisite for further operations on that text such as inferencing (see Surber & Surber, 1983), although this may not always be the case because literal recall of a text is not always related to other types of comprehension for the same text (Bransford, Barclay, & Franks, 1972). Questions designed to elicit recall of literal content were asked in order to investigate the relation between inferencing and memory for the text. Another type of question required the interpretation of a simile in the episode by integrating prior information in the text with general knowledge rather than with the Gan knowledge base. The correct interpretation of these similes depends on the specific prior information given in the episode, that is, meaning had to be inferred by integrating general knowledge and explicit text.

*Final memory for knowledge base.* After answering questions for the last episode, the subject was asked to remember the knowledge taught initially ("What are the turtles on Gan like?" "What are the bears on Gan like?"). This final memory test was used to measure whether the knowledge base was equally available, that is, equally well recalled, at the end of the story by children of different ages, and to provide a means of conditionalizing inferencing on available knowledge so that consideration was given only for inferences for which the relevant knowledge was known to be available.

## Results

The analyses addressed three questions: When children acquire and remember a knowledge base, are there developmental differences in their coherence and elaborative inferencing using that knowledge? If children fail to make an inference, is how they fail related to their age and/or to the type of inference? How are memory for literal content and the ability to integrate text and prior knowledge to interpret a simile related to coherence and elaborative inferencing?

The analyses of variance always tested age (ages 6–7, 8–9, 10–11, 12–13, 14–15) as the between-subjects factor. All post hoc tests were conducted using Duncan new multiple range tests ( $p = .05$ ).

### *Acquiring and Remembering New Knowledge*

How the knowledge base was learned was assessed by performance on the forced-choice recognition task (scores above a perfect score of 20 reflected any extra trials needed for one correct identification per item). Acquisition scores for the knowledge base are presented in Table 2. There were age differences on the task,  $F(4,46) = 3.625$ ,  $p = .012$ , such that the 6 to 7-year-olds required more repetitions of some of the items to acquire the knowledge base than did the 10- to 11-, 12- to 13-, and 14- to 15-year-olds, and the 8- to 9-year-olds required significantly more repetitions of some items to acquire the knowledge base than did the 14- to 15-year-olds. Although the youngest children did not learn the knowledge base as easily as the older children, they took very few additional trials to learn the 20 items. The mean score of 23.8 for 6 to 7-year-olds indicates that after hearing each item only once, they initially recognized between 16 and 17 of the 20 items correctly on the picture recognition task; the 3 to 4 failed and retaught items were most often passed immediately on retesting with the pictures.

How is learned knowledge remembered over the time when it must be accessed to make inferences? The final memory scores for the knowledge base (number remembered out of 20) are presented in Table 2. There were no age differences in these memory scores, so, by the end of the story, the knowledge is equally available to (i.e., can be equally recalled by) children across the age range tested. Whether knowledge is equally accessible as well as equally available is considered at a later point in this paper.

### *Inferencing*

Inferencing scores were conditionalized on memory for the knowledge base, so that only knowledge known to be available to a particular subject was analyzed in relation to that subject's correct inferencing. Proportions were calculated out of equivalent bases for the two types of inference; a  $t$  test comparing number of elaborative knowledge base items and number of coherence knowledge base items recalled on the final memory test revealed no difference between the two item sets (95% versus 93%, respectively).

The analysis tested 5 Age Groups  $\times$  2 Inference Types (coherence vs elaborative). The inferencing scores are presented in Table 3. There was a main effect

TABLE 2  
Mean Picture Recognition and Final Memory Scores (SD) for the  
Knowledge Base in Experiment 1

Age group	<i>n</i>	Picture recognition	Final memory
6-7	(9)	23.8 (.13)	18.7 (1.2)
8-9	(11)	23.0 (.10)	18.0 (2.2)
10-11	(11)	21.4 (.06)	19.3 (1.5)
12-13	(9)	22.0 (.09)	19.0 (1.2)
14-15	(11)	21.2 (.06)	19.4 (0.9)



TABLE 3  
Coherence and Elaborative Inferencing: Mean Proportion Correct (SD)  
for Experiment 1

Age group	Type of inference	
	Coherence	Elaborative
6-7	.33 (.23)	.11 (.13)
8-9	.50 (.29)	.29 (.29)
10-11	.67 (.18)	.36 (.23)
12-13	.66 (.20)	.41 (.22)
14-15	.81 (.16)	.66 (.22)

of age,  $F(4,46) = 8.917$ ,  $p < .0001$ , and a main effect of inference type,  $F(1,46) = 66.324$ ,  $p < .0001$ , with more coherence than elaborative inferences being made. The interaction was not significant. Post hoc tests revealed that 6- to 7-year-olds made fewer inferences than children from 10 to 15 years of age, and 14- to 15-year-olds made more inferences than all younger children.

### *Inferencing Failures*

Children's responses when they failed to make an inference were analyzed to investigate the possible reasons for the poorer performance of the younger children. Each failure to make an inference was classified as (1) an integration failure (e.g., the premise information from the text that Dack wished he was a turtle was part of the response given to the inference question, and the knowledge base information that turtles on Gan have ice skates attached to their feet was recalled on the final memory test of the knowledge base, but the two sources of information were not integrated to form an inference); or (2) a premise failure (e.g., the relevant item from the knowledge base was recalled on the final memory test but all or part of the premise information from the text was incompletely recalled in response to the inference question). Failures due to forgetting items from the knowledge base were infrequent (failures of knowledge and failures of both knowledge and premise accounted for 5 and 5.9% of all failures, respectively) and were not further analyzed. The data are presented in Table 4.

The analysis tested 5 Age Groups  $\times$  2 Inference Types (coherence vs elaborative)  $\times$  2 Types of Failure (integration vs premise). There were main effects of Age,  $F(4,46) = 9.289$ ,  $p < .0001$ , and Inference Type,  $F(1,46) = 47.861$ ,  $p < .0001$ , mirroring the effects for correct inference trials. The interactions are of interest here. There was a significant Type of Inference  $\times$  Type of Failure interaction,  $F(1,46) = 14.664$ ,  $p < .0004$ , that was qualified by the three-way interaction with Age,  $F(4,46) = 5.606$ ,  $p < .0009$ . Separate analyses for each age group revealed a significant interaction of Type of Inference  $\times$  Type of Failure for only the 6- to 7-year-olds,  $F(1,8) = 43.429$ ,  $p < .0002$ . For this youngest group, significantly more coherence inferencing failures were due to premise failures than to integration failures (premise failures accounted for 72% of all

TABLE 4  
Coherence and Elaborative Inferencing Failures: Mean Number (SD) of  
Integration and Premise Failures for Experiment 1

Age group	Type of failure	
	Integration	Premise
Coherence inferencing failures		
6-7	1.78 (1.09)	4.56 (2.92)
8-9	1.46 (1.04)	2.82 (1.83)
10-11	1.36 (0.81)	1.82 (1.66)
12-13	1.89 (1.45)	1.33 (0.50)
14-15	0.91 (0.70)	1.00 (1.67)
Elaborative inferencing failures		
6-7	4.78 (2.33)	3.33 (2.24)
8-9	2.82 (1.54)	3.55 (2.12)
10-11	3.82 (1.89)	2.46 (2.21)
12-13	3.00 (1.80)	2.44 (1.59)
14-15	1.36 (1.21)	1.73 (1.27)

their coherence failures), while a different pattern was observed for their elaborative inferencing failures (only 41% of failures were premise failures).

#### *Memory for Text, Inferring the Meaning of Textual Similes, and Inferencing*

Although the knowledge base is necessary for inferencing, the age-related differences in inferencing show that it is not sufficient, so other skills must also contribute to inferencing success. Regression analyses tested whether memory for actual text propositions, and the ability to integrate text and general knowledge to interpret similes, are related to coherence and elaborative inferencing in this study. Answers to literal questions were scored on a two-point system, with a single point given for partial recall of the relevant proposition, and full points given for complete recall of the proposition. Similes were scored if they were interpreted correctly. Because the percentage correct for literal and simile questions increased with age ( $F(4,46) = 5.40, p < .01$ ; and  $F(4,46) = 8.28, p < .0001$ , respectively), test age and scores for literal and simile questions were used as predictors of coherence and elaborative inferencing.

A multiple regression of age and literal and simile scores on coherence inferencing scores was significant,  $F(3,47) = 21.918, p < .0001$ , accounting for 56% of the variance. The  $\beta$  coefficients revealed a significant contribution of age and literal scores, but not of simile scores ( $t(47) = 2.05, p = .046$ ;  $t(47) = 2.33, p = .024$ ; and  $t(47) = 1.76, p = .089$ , respectively). The same regression on elaborative inferencing scores was significant,  $F(3,47) = 13.783, p < .0001$ , accounting for 43% of the variance. The  $\beta$  coefficients revealed a significant contribution only of age ( $t(47) = 2.93, p = .005$ ).

## Discussion

The results of Experiment 1 failed to support the strong age-invariance hypothesis that developmental differences in inferencing will disappear under conditions of equivalent knowledge base availability. In Experiment 1, a new knowledge base was taught to children across a broad age range and the knowledge base was shown to be equally available across that age range by the end of the story, and by extension, over the time that they were required to use the knowledge for inferencing. In addition, knowledge availability was controlled for each subject by conditionalizing inferencing on knowledge that was actually recalled. Even with a knowledge base equally available, Experiment 1 demonstrated higher rates of inferencing in middle childhood than in younger children, as well as a stable level of inferencing in middle childhood that was followed by improvements in early adolescence.

Coherence and elaborative inferencing both improved with age in Experiment 1. However, three pieces of evidence suggest that the processing characteristics of each type of inference may differ. Consistent with their relative importance for a basic understanding of the text, coherence inferences were made more frequently than were elaborative inferences at all ages. This is in keeping with the literature on adults' text processing, where it is proposed that inferences between explicit propositions in a text that are necessary for comprehension are made more frequently than nonobligatory or elaborative inferences (Duffy, 1986; Garrod et al., 1990; Keenan et al., 1984; McKoon & Ratcliff, 1986; Potts, Keenan, & Golding, 1988; review in Whitney, 1987). It is also consistent with recent studies of children's inferencing (Casteel, 1993), and extends those findings by showing that children as young as 6 and 7 years of age seem sensitive to the causal constraints operating within a story.

Coherence and elaborative inferencing failures had different origins in young children. While failures of elaborative inferencing in the youngest group were characterized by similar degrees of integration and premise errors, coherence inferencing failures were far more likely to reflect an inability to remember the premise information. Failure to resolve textual inconsistencies such as those posed by the coherence inference items would necessarily impair understanding of the story. The failure of younger children to resolve many inconsistencies likely resulted in losses in comprehension that are signaled by their difficulties in recalling inconsistent text information: text that is difficult to understand is also likely to be poorly remembered (Thorndyke, 1977). The finding that the youngest age group was less likely to repair textual inconsistencies is in keeping with the literature on comprehension monitoring showing that, while young children have the capacity to repair textual inconsistencies, they may lack either a strategic sense of when or how often to do so, or the ability to sustain this capacity over time (Singer & Flavell, 1981).

Regardless of age, memory for literal text was related to coherence inferencing but not to elaborative inferencing. One hypothesis about the role of memory in

text comprehension is that working memory buffers recent text propositions and coordinates what was previously read or heard with current text to ensure that coherence is maintained (Whitney et al., 1991). Children who are better at recalling the literal text base may also be better able to hold inconsistent textual information in memory long enough to restore coherence. In contrast, because an elaborative inference is not required for maintaining coherence, elaborative inferencing may rely to a greater extent on processes other than holding text in memory.

In sum, Experiment 1 showed that: (1) when a knowledge base was equally available to children of different ages, developmental changes in inferencing are still present; (2) coherence and elaborative inferences may have different processing characteristics. The evidence for the latter is that coherence inferences are made more frequently than elaborative inferences at all ages, that memory for text is related to coherence but not elaborative inferencing, and that the source of inferencing failures in young children differs for coherence and elaborative inferencing.

## EXPERIMENT 2

Mere availability of knowledge in memory does not ensure that such knowledge will be accessed to make inferences to understand a text. The accessibility of an object concept in sentences prior to an outcome sentence is a critical determinant of whether children will make an inference about that object (Ackerman, Silver, & Glickman, 1990). For adults, fast retrieval or ease of accessibility of information within a text supports automatic inference processes, particularly those implicated in elaborative inferencing (McKoon & Ratcliff, 1989, 1992). In both these cases, the information important for making the inference has already been presented in the text, and it is the ease of accessing previously encountered text-based information that proves important for later inferencing. In knowledge-base inferencing, however, the information used to make the inference is external to the text in the sense that it is part of the individual's general world knowledge. If the same general principles apply to inferencing with implicit or knowledge-based information, then easily accessible general knowledge from semantic memory may be used to make inferences, but knowledge that is available, though not as accessible, may be less likely to be used for this purpose.

Information in semantic memory may be made more or less accessible. Common properties of objects are generally more accessible than less common properties (Barsalou, 1982), though context can affect the relative accessibility of this information (Barsalou, 1987). Foregrounding a particular concept in a text by repeating it across sentences influences the accessibility of semantic information about that concept (Whitney, Ritchie, & Crane, 1992). The way in which an individual's knowledge base is internally organized in terms of the number and level of connections between elements of knowledge (see Kintsch, 1994, for a discussion) might be expected to affect knowledge accessibility, as could also the

goals and strategies that a person brings to a text (Graesser & Kreuz, 1993; McKoon & Ratcliff, 1992).

Although the knowledge base in Experiment 1 was equally available to children of different ages by the end of the story, this does not guarantee that the knowledge base was equally available during the presentation of the story episodes. To better ensure that the knowledge base is equally available during the story, Experiment 2 used a cued recall of the knowledge base before the story was read. The absence of age-related differences on this prestory recall of the knowledge base would provide better evidence that the knowledge base was equally available not only at the end of the story, but also before the story was presented. This recall of the knowledge base before the story is presented also serves to provide a repetition of the knowledge base that may strengthen the degree to which the knowledge base is encoded.

Experiment 2 also investigated the effect of more accessible (as contrasted with less accessible) knowledge-based information on making inferences requiring that information. The relation between knowledge base accessibility and inferencing was explored to consider how the accessibility of an individual knowledge base item predicts inferencing with that particular item. Here, accessibility was indexed by the *speed* with which individual knowledge base items could be retrieved from memory.

Data from Experiment 1 had suggested that coherence and elaborative inferences differ in how they are processed, and that younger children have imperfect mastery of each type of inference. The basis of the processing differences and the reasons for the difficulties of younger children, however, are unclear. Coherence inferences require causal reasoning in terms of inferring *why* something happened, while elaborative inferences may require a different sort of reasoning that specifies *what* something was like. It may be that younger children have difficulties with one or both types of reasoning. For example, although the ability to make causal inferences begins to develop between 3 and 4 years of age (Das Gupta & Bryant, 1989), children in the early grades may still have some difficulty integrating knowledge and premise information to make a causal connection.

If younger children are poorer at integrating information to make inferences, even in simple processing situations, then their difficulty in inferencing during text comprehension (a relatively complex processing situation), may reflect basic limitations in the integration and reasoning skills needed for inferencing. One way to investigate this issue is to directly ask the "why" and "what" inference questions in a context simpler than ongoing text processing, that is, in a situation with less complex processing demands (see Ackerman, 1984). Alternatively, inferencing problems in younger children may be specific to text processing and not to the inferencing operation *per se*. Perhaps younger children are particularly poor at inferencing in situations requiring the complex information processing necessary for understanding a story, in which case they would be poor at inferencing during text comprehension, but not in less complex processing situations.

A comparison of inferencing in more versus less complex processing situations might reveal any developmental differences in the reasoning needed for the two types of inferences, and thereby clarify why younger children have difficulty with knowledge-based inferencing.

Does the accessibility of individual knowledge base items predict inferencing with those items regardless of age, and is knowledge accessibility more important for making one type of inference rather than another? How do coherence and elaborative inferencing in the context of text comprehension differ from inferencing in less complex processing situations? Experiment 2 addressed these questions.

## Method

### *Subjects*

Ninety-six children between the ages of 6 and 15 years were tested individually, with equal numbers of girls and boys. There were thirteen 6- to 7-year-olds ( $M$  age = 6.98; range = 6.11–7.90); twenty-five 8- to 9-year-olds ( $M$  age = 8.88; range = 8.03–9.98); twenty-two 10- to 11-year-olds ( $M$  age = 10.94; range = 10.01–11.97); twenty 12- to 13-year-olds ( $M$  age = 12.96; range = 12.07–13.92); and sixteen 14- to 15-year olds ( $M$  age = 15.22; range = 14.12–16.16). The children participated in a larger study of reading comprehension of which this was one part (this accounts for the uneven numbers of subjects in each age group, as for the reading study, subjects were initially recruited on the basis of grade rather than age). The children were from the same school system as those in Experiment 1 and were selected using similar criteria.

### *Procedure*

A procedure similar to that in Experiment 1 was followed, with some changes pertinent to the specific goals of Experiment 2. A verbal recall of the knowledge base was inserted between the forced-choice picture recognition task and presentation of the story. This test contained questions such as “What are the turtles on Gan like” and “What are the bears on Gan like?” Responses to these questions were timed from the offset of the question to the onset of the response to provide a measure of accessibility of each knowledge base item. Each question had the same grammatical structure so that the relevant topic being tested (e.g., turtles, bears) was mentioned in the same position in each test sentence. Any item not answered correctly was retaught and retested at the end of this phase.

The second change in Experiment 2 was that subjects were asked two types of inferencing questions: (1) the indirect questions used in Experiment 1 that measure inferences made in comprehending the story and (2) direct questions that measure the ability to integrate the knowledge base with premise information in situations of minimal information processing complexity. The direct equivalent of the indirect question “What did Dack wish?” would be “Why did Dack wish he was a turtle?” and the direct equivalent of “What did the children take out of

their bags?" would be "What were the children's bear fur coats like?" The direct questions were asked in a block immediately after the final memory test for the knowledge base.

Direct questions reduce processing complexity for two reasons: The child does not have to evaluate whether an inference should be made (the "why" or "what" question cues the inference); and the information load of the task is low because the relevant premise information is included in the question (strictly speaking, the story need not have been experienced at all in order for the inference to be made), and the relevant knowledge base items have just been recalled one to three minutes previously.

The visual illusions test was removed as the distractor task and was replaced with a 10-s interval during which the experimenter turned on the tape recorder and prepared the materials for the next episode. For children from grades 3 to 10, half of the episodes were read and half were listened to. The listened-to and read episodes were counterbalanced across subjects. There was no difference in the number of either elaborative or coherence inferences made in the read versus the listened-to conditions at any grade, so the data were collapsed across this dimension for comparison to the younger children.

## Results

Analyses similar to those in Experiment 1 are mentioned briefly when they yielded results identical to those obtained in the first experiment. The Duncan new multiple range test was used as the post hoc procedure, as it uses Kramer's modification for unequal sample sizes.

### *Acquiring and Remembering Knowledge*

The scores for the forced-choice picture recognition task are presented in Table 5. Results were similar to those in Experiment 1: The 6- to 7-year-olds required more learning trials than did children 10 years of age and older. While the 8- to 9-year-olds in Experiment 1 had required significantly more trials than the 14- to 15-year-olds, here the age effect was not significant.

Verbal recall of the knowledge base was scored out of 20, reflecting the subject's score on the first pass of the verbal questions (see Table 5). Analyses

TABLE 5  
Mean Picture Recognition, Verbal Recall, and Final Memory Scores (SD) for the Knowledge Base in Experiment 2

Age group	<i>n</i>	Picture recognition	Verbal recall	Final memory
6-7	(13)	24.8 (3.9)	17.4 (2.0)	19.4 (0.8)
8-9	(25)	23.3 (2.2)	18.4 (1.6)	19.6 (0.6)
10-11	(22)	22.2 (1.7)	18.2 (2.2)	19.6 (0.8)
12-13	(20)	22.6 (2.7)	18.8 (1.2)	20.0 (0.0)
14-15	(16)	21.7 (1.9)	18.0 (2.0)	19.6 (0.6)

on the scores for the verbal recall of the knowledge base and for the final memory test of the knowledge base revealed no age effects (see Table 5).

### *Inferencing*

*Indirect Questions.* A 5 Age Group  $\times$  2 Inference Type (coherence vs elaborative) analysis of variance with the latter factor tested within subjects was conducted on the mean inferencing scores to indirect questions (see Table 6).

There was a main effect of age,  $F(4,91) = 5.907, p < .0003$ , such that 6- to 7-year-olds made fewer inferences than children from 10 to 15, and 14- to 15-year-olds made more inferences than children from 8 to 9. As in Experiment 1, there was a main effect of inference type,  $F(1,91) = 80.154, p < .0001$ , such that more coherence than elaborative inferences were made. The interaction was not significant.

*Direct Questions.* A 5 Age Group  $\times$  2 Inference Type (coherence vs elaborative) analysis of variance was conducted on the inferencing scores to direct questions (see Table 6). There was a main effect of age,  $F(4,91) = 5.183, p < .0008$ , such that 6- to 7- and 8- to 9-year-olds made fewer inferences than 10- to 15-year-olds. There was also a main effect of inference type,  $F(1,91) = 34.907, p < .0001$ , such that more elaborative inferences were made than coherence inferences. The interaction was not significant.

To investigate whether the difficulties of the younger children in inferencing during text comprehension are due to a fundamental problem in making the inferences themselves (as measured in the less complex processing condition), the scores for inferencing to direct questions were used as covariates in analyses of inferencing to indirect questions. No Age effects were obtained. The difficulties of younger children in making inferences during text processing, then, can be accounted for by differences in the ability to make the inferences in isolation from an ongoing oral text.

### *Memory for Text, the Ability to Infer the Meaning of Similes, and Inferencing*

As in Experiment 1, the ability to recall literal content was related to coherence inferencing but not to elaborative inferencing. In Experiment 2, however, the

TABLE 6  
Coherence and Elaborative Inferencing: Mean Proportion Correct (SD) for Indirect and Direct Questions in Experiment 2

Age group	Coherence inferencing		Elaborative inferencing	
	Indirect questions	Direct questions	Indirect questions	Direct questions
6-7	.37 (.35)	.71 (.28)	.17 (.19)	.86 (.16)
8-9	.51 (.24)	.78 (.21)	.36 (.19)	.87 (.19)
10-11	.60 (.21)	.91 (.09)	.36 (.19)	.94 (.08)
12-13	.68 (.27)	.93 (.12)	.44 (.25)	.97 (.05)
14-15	.71 (.21)	.93 (.09)	.52 (.24)	.98 (.05)



ability to interpret similes was also related to both coherence and elaborative inferencing ( $t(91) = 5.15, p < .0001$ ;  $t(91) = 3.446, p < .001$ , respectively). There was also a trend ( $p = .08$ ) for simile interpretation to be related to coherence inferencing in Experiment 1. In any case, the integration skills needed to interpret the similes in the story may sometimes partially overlap with those needed to make inferences.

### *Accessibility of Knowledge and Inferencing*

This issue was addressed by using the Cochran–Mantel–Haenszel statistic (CMH), a form of extended  $\chi^2$ . The CMH tested whether making an inference was related to speed of access to the pertinent knowledge base item while controlling for any interactions that may be occurring with age and type of inference. This nonparametric statistic was used to look at the probability of making an inference when access to relevant knowledge base information was fast versus when it was slow.

Younger children are slower at accessing knowledge (Gitomer, Pellegrino, & Bisanz, 1983) and they are poorer at inferencing (although, of course, this correlation need not entail that slow knowledge access *causes* problems in inferencing). Our approach to investigating the nature of the relation between access speed and inferencing, therefore, is one in which we control for age-related differences in access speed. If access speed is related to inferencing itself, then this relation should be present even after more general developmental differences in speed are factored out. Mean response times for each age group were calculated by considering response times to all knowledge base items within an age group, so that separate means were calculated for each age group. Individual children's response times were classified as "fast" if they were more than half a standard deviation below the mean for their age group and as "slow" if they were half a standard deviation above the mean. The inferences were then matched with these fast and slow responses to the knowledge base so that four scores for each of coherence and elaborative inferencing were derived for each child: fast access and inference made; fast access and inference not made; slow access and inference made; slow access and inference not made.

Is there a relation between access speed and inferencing, controlling for type of inference? The CMH statistic also yields an odds ratio (RR) that characterizes the magnitude of the relation between two categorical variables. For example, an RR of 2.0 would mean that quickly accessed knowledge is twice as likely to be used to make an inference than less quickly accessed knowledge. The association between speed and inferencing was significant,  $CMH = 25.021, p < .0001$ , and quickly accessed knowledge was about twice as likely to be used in inferencing than was more slowly accessed knowledge ( $RR = 2.12$ ).

The next analysis considered the relation between access speed and inferencing, controlling for inference type and age. Because this analysis was significant,  $CMH = 26.5, p < .0001$ ,  $\chi^2$ 's are used to investigate the relation between access speed and inferencing for each type of inference for each age group. Speed of

access was related to both coherence and elaborative inferring,  $\chi^2 = 8.795$ ,  $p < .003$ ; and  $\chi^2 = 17.2$ ,  $p < .0001$ , respectively ( $RR = 1.8$  vs  $2.5$ , respectively).

The relation between speed of access and each type of inference changed over the course of development. Figure 2 illustrates this using the odds ratios. Speed of access was related to coherence inferring for only the 6- to 7-year-olds,  $\chi^2 = 5.233$ ,  $p < .02$ , and 8- to 9-year-olds,  $\chi^2 = 4.545$ ,  $p < .03$ . In contrast, speed of access was related to elaborative inferring for the 10- to 11-year-olds,  $\chi^2 = 6.149$ ,  $p < .02$ , and the 12- to 13-year-olds,  $\chi^2 = 4.403$ ,  $p < .04$ . While the odds ratio for elaborative inferring also appears greater than that for coherence inferring in the oldest age group (see Fig. 2), the analysis failed to reach significance.

## Discussion

Experiment 2 suggests that knowledge accessibility is important for knowledge-based inferring, but that its effects are also related to the age of the child and the function of the inference in text comprehension. Regardless of age, highly accessible knowledge is twice as likely to be integrated with text-based information than is available but less accessible knowledge. Knowledge accessibility is more important for coherence inferring in younger children and less important for older children. The relation between knowledge accessibility and elaborative inferring generally becomes more pronounced with increasing age; in young children, this relationship is somewhat unclear, possibly because they make relatively few elaborative inferences. The accessibility of semantic information, then, seems as important for knowledge-based inferring as it is for text-based inferring (Ackerman et al., 1990).

By comparing inferring in the context of story comprehension as opposed to a less complex processing context, Experiment 2 tested whether younger children

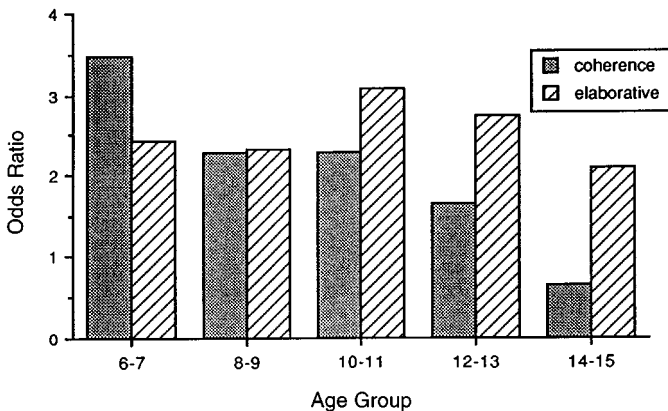


FIG. 2. Odds ratios as a function of age and type of inference.

make fewer coherence and elaborative inferences during text comprehension than do older children partly because of the complex processing requirements involved in understanding stories or, alternatively, because of a more fundamental problem with the reasoning and integration skills involved in making these two types of inferences.

Even in the less complex processing situation, the two youngest groups of children made fewer coherence and elaborative inferences than older children, despite the fact that all children made more inferences in this condition than in the text comprehension condition. Apparently, inferencing was facilitated in the less complex context. Age-related differences in inferencing in the less complex processing context were found to account for the age differences in the more complex text comprehension condition, suggesting that there is some basic limitation in inferencing in younger children that occurs irrespective of both the knowledge base and the processing context.

One important difference emerged, however, between inferencing in the more and less complex processing conditions: Coherence inferences were made more often than elaborative inferences during text comprehension, but the opposite pattern was found in the less complex processing condition. The idea that the integration or reasoning skills that are needed for elaborative inferencing (what is a situation like) are simpler than those needed for coherence inferencing (why did something happen) is consistent with the view that, while elaborative inferences are made less frequently than coherence inferences during on-line comprehension, they nevertheless can be generated readily from a mental representation of the text (Garnham, 1982). Our data further suggest that it is most particularly in the context of discourse or text that coherence inferences will be made, not unexpected under the view that coherence inferences are often made during comprehension, being necessary for interpreting text at a local level (Oakhill & Garnham, 1988).

TABLE 7

Coherence vs Elaborative Inferencing: Knowledge Accessibility and Processing Characteristics

	Coherence inferences	Elaborative inferences
Knowledge accessibility		
Younger children	More important	Unclear
Older children	Less important	More important
Processing characteristics		
Frequency when understanding texts	More frequent	Less frequent
Frequency when directly elicited in a simple processing context	Less frequent	More frequent
The ability to recall specific propositions from the text	Is related to the ability to make this type of inference	Is not related to the ability to make this type of inference

## GENERAL DISCUSSION

*Inferencing and the Knowledge Base*

Experiments 1 and 2 have used a novel approach to studying developmental differences in knowledge-based inferencing: They manipulated the knowledge base so that all subjects had the same knowledge available to them before hearing a story. Contrary to the strong age-invariance hypothesis that equating for knowledge would lead to similar rates of inferencing in younger and older children, developmental changes in inferencing were obtained in both studies. Similar findings have been obtained in studies of skills other than inferencing, where the knowledge base has been directly manipulated as contrasted with those that have used high- and low-knowledge subjects. DeMarie-Dreblow (1991), for example, found that teaching a new knowledge base still resulted in age-related differences in memory.

A knowledge base, however, consists of not only a set of facts, but also a rich set of connections between facts. Studies with high- and low-knowledge subjects probably measure more than differences due to varying domain knowledge; they also likely measure structural or qualitative differences in how domain knowledge is represented. Further studies using newly acquired knowledge bases might investigate the processes by which knowledge becomes represented in a network of associations and how inferencing might change as a function of changes in how knowledge is represented.

For example, different learning conditions may lead to different levels or types of learning (e.g., Underwood & Ekstrand, 1966) or to differences in the way information is represented in memory, and learning continues past the point at which recall is accurate and even after access speed asymptotes (e.g., LeMoine, Levy, & Hutchinson, 1993). Studies of the development of memory have demonstrated the existence of age-forgetting relationships that are not dependent on initial levels of learning (Brainerd, Reyna, Howe, & Kingma, 1990).

All of these findings suggest that there are several factors that could influence the way in which knowledge comes to be represented and accessed in children of different ages. Future studies using novel knowledge bases might study how a knowledge base itself develops and how different types of knowledge acquisition affect inferencing in children of different ages. For example, a knowledge base that is explicitly interconnected might be taught using a more protracted and different type of knowledge acquisition phase, or inferencing could be compared under different conditions of knowledge base acquisition. Certainly, knowledge is usually acquired through more than the one or two exposures to the knowledge base given in Experiments 1 and 2. In future studies it will be important to investigate how inferencing changes as a function of both the number of times knowledge has been presented in the past and the contexts in which that knowledge has been encountered.

The knowledge accessibility data in Experiment 2 do provide evidence that

equally available knowledge is not equally accessible, and that it is knowledge accessibility that is important for knowledge-based inferencing. Information that was more rapidly accessible before hearing the story was also more likely to be used to make inferences during story comprehension. It would seem, then, that the accessibility of information external to the text is important for inferences that use that information. In an analogous manner, the accessibility of prior text in working memory is important for text-based inferencing (Singer, Andrusiak, Reisdorf, & Black, 1992).

### *Developmental Changes in Coherence and Elaborative Inferencing*

Although both coherence and elaborative inferencing improved with age, Experiments 1 and 2 highlighted several differences between the two types of inferencing: Coherence but not elaborative inferencing was related to the ability to recall literal text; and more coherence than elaborative inferences were made in the context of story comprehension, even though the opposite was true in a less complex processing context. It may be important to be able to maintain inconsistent textual information in memory until it can be resolved through making an inference. The sources of coherence inferencing failures in the youngest children support this notion, because they had difficulty recalling inconsistent premise information from the text.

Some aspects of inferencing must be unique to story comprehension because the function of the inference in comprehension was more predictive of inferencing during text comprehension than was inferencing skill *per se*. Although elaborative inferences were more readily made under conditions of less processing complexity, they were less likely to be made during story comprehension. Also, the seemingly more difficult coherence inference was made more often during text comprehension. These results are analogous to those in studies of adult inferencing and to recent studies of children's inferencing (Casteel, 1993) where inferences necessary for making sense of the text are made more often than those inferences that are nonobligatory in terms of a minimal level of understanding. Our youngest children had more difficulty making coherence inferences than did older children, but they still made more coherence inferences than elaborative inferences during story comprehension. The present study extends previous findings by showing that children as young as 6 years of age are sensitive to the causal constraints operating within stories even though inferences that restore coherence are actually more difficult for them to make than are inferences that elaborate on the story.

### *Knowledge Accessibility and the Development of Coherence and Elaborative Inferencing*

Highly accessible knowledge was used more often than less accessible knowledge to make inferences, but with increasing age, knowledge accessibility seemed to play a lesser role in coherence than in elaborative inferencing. The reasons for this may be related to how children of different ages understand text

and to how the comprehension process places different constraints on the time course of elaborative and coherence inferencing.

Inferences that maintain coherence by bridging two propositions or ideas within a text are routinely made by fluent readers during comprehension (Duffy, 1986; Keenan et al., 1984; McKoon & Ratcliff, 1986). These inferences are important for a minimal level of comprehension, so they may be made more rapidly when the relevant text propositions are easily accessible. When the relevant information is not as accessible, a more time-consuming memory search may be undertaken before subsequent text is processed. Our data suggest that knowledge-based inferences, too, are more likely to be made when the required knowledge is highly accessible, although an attempt to maintain coherence will still be made, particularly by older children, even when the knowledge is not highly accessible (provided that it is retrievable).

A high level of accessibility facilitated coherence inferencing in the youngest groups. While children may not routinely monitor textual inconsistencies until they are at least in the middle primary grades (Markman, 1979), their variable comprehension monitoring may sometimes be compensated for when the knowledge base is highly accessible. Older children, demonstrably better at monitoring story coherence, are less influenced by knowledge accessibility, and so they may attempt to maintain coherence if the pertinent knowledge is available, even if it is not highly accessible. Studies using young or low-aptitude subjects who are highly knowledgeable in a particular area may partly measure the compensatory effects of highly accessible knowledge on the performance of various cognitive operations.

Elaborative inferencing, on the other hand, occurs relatively less frequently during comprehension (McKoon & Ratcliff, 1986; Garrod et al., 1990), so these inferences may require an accessible knowledge base (Graesser & Kreuz, 1993). In Experiment 2, elaborative inferencing was closely related to knowledge accessibility with increasing age. It may be that the growth of the knowledge base itself, with ensuing changes in knowledge accessibility, is responsible for age-related increases in elaborative inferencing.

The importance of knowledge accessibility is evidenced in studies in which more spontaneous or on-line elaborative inferencing occurs with adult readers when they are taught a rich knowledge base, and immersed in a multi-episode story that draws on that knowledge (e.g., Morrow et al., 1989, 1990). While our measures do not distinguish between the inferences made at the time the story is heard from those made only during questioning, future studies might address on-line monitoring of knowledge base access and inferencing during children's text processing, possibly by using reading speed measures such as those employed by Casteel (1993). Further, the relation between knowledge base accessibility and inferencing might be elucidated by investigating inferencing in different types of story comprehension contexts such as listening versus reading, and reading for different purposes or goals. (For theoretical and methodological discussions of the use of different types of inferencing measures, methods, and

texts, see Singer, 1993; Suh & Trabasso, 1993; & van den Broek, Fletcher, & Ridsen, 1993.)

The experiments reported here used an approach that directly manipulated the knowledge base in order to study developmental aspects of knowledge-based inferencing and to reveal findings pertinent to knowledge-based inferencing in general. Three new findings about knowledge-based inferencing emerged: (1) Developmental changes in inferencing are still apparent when a specified knowledge base is taught and is equally available to all children; (2) throughout development, the accessibility of knowledge is important for making inferences during text comprehension; and (3) coherence inferences are made more frequently than elaborative inferences early in the development of text comprehension skills, even though the computation needed to make elaborative inferences may be simpler than that needed for coherence inferencing.

### APPENDIX: KNOWLEDGE BASE

The rivers and ponds on Gan are filled with orange juice.

The people on Gan don't have noses.

The trees on Gan have pink leaves.

The shoes from Gan have wings.

The mushrooms on Gan are as tall as the children.

The bears on Gan have bright blue fur.

The raindrops on Gan are shaped like triangles.

The cats on Gan have to be dressed in fancy clothes before they can go outside.

The mountains on Gan are made out of bubbles.

The walls and roofs of the houses on Gan are built of glass.

The frogs on Gan glow in the dark.

The fish on Gan have spikes all over their bodies.

The mittens on Gan are square-shaped.

The book covers on Gan are made of popcorn.

The canaries on Gan say "moo."

The flowers on Gan are hot like fire.

On Gan, all the people have bright green hair.

The turtles on Gan have ice skates attached to their feet.

The moon on Gan is shaped like a diamond.

Socks from Gan have zippers down the front of them.

### REFERENCES

- Ackerman, B. P. (1984). Storage and processing constraints on integrating story information in children and adults. *Journal of Experimental Child Psychology*, **38**, 64-92.
- Ackerman, B. P. (1986). Referential and causal coherence in the story comprehension of children and adults. *Child Development*, **57**, 336-366.
- Ackerman, B. P. (1988). Reason inferences in the story comprehension of children and adults. *Child Development*, **59**, 1426-1442.
- Ackerman, B. P., Silver, D., & Glickman, I. (1990). Concept availability in the causal inferences of children and adults. *Child Development*, **61**, 230-246.

- Barsalou, L. W. (1982). Context-independent and context-dependent information in concepts. *Memory and Cognition*, **10**, 82–93.
- Barsalou, L. W. (1987). The instability of graded structure: implications for the nature of concepts. In U. Neisser (Ed.), *Concepts and conceptual development: Ecological and intellectual factors in categorization*. Cambridge: Cambridge Univ. Press.
- Bjorklund, D. F., & Bernholtz, J. E. (1986). The role of knowledge base in the memory performance of good and poor readers. *Journal of Experimental Child Psychology*, **41**, 367–373.
- Bjorklund, D. F., & Buchanan, J. J. (1989). Developmental and knowledge base differences in the acquisition and extension of a memory strategy. *Journal of Experimental Child Psychology*, **48**, 451–471.
- Brainerd, C. J., Reyna, V. F., Howe, M. L., & Kingma, J. (1990). Development of forgetting and reminiscence. *Monographs of the Society for Research in Child Development*, **55**, (3–4, Serial No. 222).
- Bransford, J. D., Barclay, J., & Franks, J. J. (1972). Sentence memory: A constructive versus interpretive approach. *Cognitive Psychology*, **3**, 193–209.
- Carroll, J. B., & White, M. N. (1973). Age-of-acquisition norms for 220 picturable nouns. *Journal of Verbal Learning and Verbal Behavior*, **12**, 563–576.
- Casteel, M. A. (1993). Effects of inference necessity and reading goal in children's inferential generations. *Developmental Psychology*, **29**, 346–357.
- Ceci, S. J., & Liker, J. K. (1986). A day at the races: A study of IQ, expertise, and cognitive complexity. *Journal of Experimental Psychology: General*, **115**, 255–266.
- Chase, W. G., & Simon, H. A. (1973). The mind's eye in chess. In W. G. Chase (Ed.), *Visual information processing*. New York: Academic Press.
- Chi, M. T. H. (1978). Knowledge structures and memory development. In R. S. Siegler (Ed.), *Children's thinking: What develops? Hillsdale, NJ: Erlbaum*.
- Das Gupta, P., & Bryant, P. E. (1989). Young children's causal inferences. *Child Development*, **60**, 1138–1146.
- DeMarie-Dreblow, D. (1991). Relation between knowledge and memory: A reminder that correlation does not imply causality. *Child Development*, **62**, 484–498.
- Duffy, S. A. (1986). Role of expectations in sentence integration. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **12**, 208–219.
- Garnham, A. (1982). Testing psychological theories about inference making. *Memory and Cognition*, **10**, 341–349.
- Garrod, S., O'Brien, E. J., Morris, R. R., & Rayner, K. (1990). Elaborative inferencing as an active or passive process. *Journal of Experimental Psychology: Learning, Memory and Cognition*, **16**, 250–257.
- Gitomer, D. H., Pellegrino, J. W., & Bisanz, J. (1983). Developmental change and invariance in semantic processing. *Journal of Experimental Child Psychology*, **35**, 56–80.
- Glucksberg, S., Brown, M., & McGlone, M. (1993). Conceptual metaphors are not automatically accessed during idiom comprehension. *Memory and Cognition*, **21**, 711–719.
- Graesser, A. C., & Kreuz, R. J. (1993). A theory of interference generation during text comprehension. *Discourse Processes*, **16**, 145–160.
- Johnson, H., & Smith, L. B. (1981). Children's inferential abilities in the context of reading to understand. *Child Development*, **52**, 1216–1223.
- Johnson-Laird, P. N. (1983). *Mental models: Towards a cognitive science of language, inference, and consciousness*. Cambridge, MA: Harvard Univ. Press.
- Keenan, J. M., Baillet, S. D., & Brown, P. (1984). The effects of causal cohesion on comprehension and memory. *Journal of Verbal Learning and Verbal Behavior*, **23**, 115–126.
- Keil, F. (1986). Conceptual domains and the acquisition of metaphor. *Cognitive Development*, **1**, 73–96.
- Kintsch, W. (1994). Text comprehension, memory, and learning. *American Psychologist*, **49**, 294–303.



- Lemoine, H. E., Levy, B. A., & Hutchinson, A. (1993). Increasing the naming speed of poor readers: Representations formed across repetitions. *Journal of Experimental Child Psychology*, **55**, 297–328.
- Markman, E. M. (1979). Realizing that you don't understand: Elementary school children's awareness of inconsistencies. *Child Development*, **50**, 643–655.
- McKoon, G. Ratcliff, & Ratcliff, R. (1986). Inferences about predictable events. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **12**, 82–91.
- McKoon, G., & Ratcliff, R. (1989). Semantic associations and elaborative inference. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **15**, 326–338.
- McKoon, G., & Ratcliff, R. (1990). Dimensions of inference. In A. C. Graesser & G. H. Bower (Eds.), *Inferences and text comprehension* (pp. 313–328). San Diego: Academic Press.
- McKoon, G., & Ratcliff, R. (1992). Inference during reading. *Psychological Review*, **99**, 440–466.
- Morrow, D. G., Bower, G. H., & Greenspan, S. L. (1989). Updating situation models during narrative comprehension. *Journal of Memory and Language*, **28**, 292–312.
- Morrow, D. G., Bower, G. H., & Greenspan, S. L. (1990). Situation-based inferences during narrative comprehension. In A. C. Graesser & G. H. Bower (Eds.), *Inferences and text comprehension* (pp. 123–135). San Diego Academic Press.
- Nicholas, D. W., & Trabasso, T. (1980). Toward a taxonomy of inferences for story comprehension. In F. Wilkening, J. Becker & T. Trabasso (Eds.), *Information integration by children* (pp. 243–265). Hillsdale, NJ: Erlbaum.
- Oakhill, J., & Garnham, A. (1988). *Becoming a skilled reader*. Oxford: Basil Blackwell.
- Paris, S. G., & Upton, L. R. (1976). Children's memory for inferential relationships in prose. *Child Development*, **47**, 660–668.
- Potts, G. R., Keenan, J. M., & Golding, J. M. (1988). Assessing the occurrence of elaborative inferences: Lexical decision versus naming. *Journal of Memory and Language*, **27**, 399–415.
- Schmidt, C. R., & Paris, S. G. (1983). Children's use of successive clues to generate and monitor inferences. *Child Development*, **54**, 742–759.
- Schneider, W., Korkel, J., & Weinert, F. E. (1989). Domain-specific knowledge and memory performance: A comparison of high- and low-aptitude children. *Journal of Educational Psychology*, **81**, No. 3, 306–312.
- Singer, J. B., & Flavell, J. H. (1981). Development of knowledge about communication: Children's evaluations of explicitly ambiguous messages. *Child Development*, **52**, 1211–1215.
- Singer, M. (1993). Global inferences of text situations. *Discourse Processes*, **16**, 161–168.
- Singer, M., Andrusiak, P., Reisdorf, P., & Black, N. L. (1992). Individual differences in bridging inference processes. *Memory and Cognition*, **20**, 539–548.
- Suh, S., & Trabasso, T. (1993). Inferences during reading: Converging evidence from discourse analysis, talk-aloud protocols, and recognition priming. *Journal of Memory and Language*, **32**, 279–300.
- Surber, J. R., & Surber, C. F. (1983). Effects of inference on memory for prose. *Merrill-Palmer Quarterly*, **29**, 197–207.
- Thorndyke, P. W. (1977). Cognitive structures in comprehension and memory of narrative discourse. *Cognitive Psychology*, **9**, 77–110.
- Underwood, B. J., & Ekstrand, B. R. (1966). An analysis of some shortcomings in the inference theory of forgetting. *Psychological Review*, **73**, 540–549.
- van den Broek, P., Fletcher, C. R., & Ridsen, K. (1993). Investigations of inferential processes in reading: A theoretical and methodological integration. *Discourse Processes*, **16**, 169–180.
- Waggoner, J. E., & Palermo, D. S. (1989). Betty is a bouncing bubble: Children's comprehension of emotion-descriptive metaphors. *Developmental Psychology*, **25**, 152–163.
- Whitney, P. (1987). Psychological theories of elaborative inferences: Implications for schema-theoretic views of comprehension. *Reading Research Quarterly*, **22**, 299–310.
- Whitney, P., Ritchie, B. G., & Clark, M. B. (1991). Working memory capacity and the use of elaborative inferences in text comprehension. *Discourse Processes*, **14**, 133–145.

- Whitney, P., Ritchie, B. G., & Crane, R. S. (1992). The effect of foregrounding on readers' use of predictive inferences. *Memory and Cognition*, **20**, 424-432.
- Whitney, P., & Williams-Whitney, D. (1990). Toward a contextualist view of elaborative inferences. In A. C. Graesser & G. H. Bower (Eds.), *Inferences and text comprehension* (pp. 279-293). San Diego Academic Press.
- Yekovich, F. R., Walker, C. H., Ogle, L. T., & Thompson, M. A. (1990). The influence of domain knowledge on inferencing in low-aptitude individuals. In A. C. Graesser & G. H. Bower (Eds.), *Inferences and text comprehension* (pp. 259-278). San Diego.
- Zabucky, K., & Ratner, H. H. (1986). Children's comprehension monitoring and recall of inconsistent stories. *Child Development*, **57**, 1401-1418.

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