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Memory for Embedded and Sequential Story Structures

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Children's and adults' memory for multiple-episode stories having sequential as compared to embedded structures was examined in two experiments. The story events and states were virtually identical in the two structures; however, the sequencing of the events and states was manipulated to produce sequential causal chain and embedded causal network structures. Recall memory and causal explanations for story events were examined in Experiment 1 for adults at immediate and delayed tests and in Experiment 2 for fifth and third grade children. Patterns of differential recall for specific information in the stories were generally consistent with recursive network models. Variance in recall was predicted by story category. The predictive importance of number of causal connections and level in an embedded goal hierarchy varied as a function of structure, time of test, and age. Causal explanations for goals and for goal-attaining actions also reflected the hypothesized differences between causal chain and causal network structures in all four groups. Goals were given as causal explanations far more frequently than would have been expected on the basis of the recall data. This "paradox" suggests the importance of understanding the assumptions that story tellers or retellers make regarding the "natural" inference processes of their audiences. © 1986 Academic Press, Inc.

Over the past decade there have been several models proposed to account for narrative recall by adults and children. Despite terminological variation, the majority of these models assume that narratives consist of motivated, goal-directed action sequences, or episodes. Episodes are, at least, chronologically, but more typically, causally related to one another (e.g., Black & Bower, 1979; Johnson & Mandler, 1980; Lichtenstein & Brewer, 1980; Rumelhart, 1975; Stein & Glenn, 1979; Stein & Goldman, 1981; Stein & Trabasso, 1982). In addition to relationships between episodes, events within the episode manifest a causal structure, the essence of which is the execution of some action(s), motivated or caused by preceding external and/or internal events that have caused a change of state in the story world. If successful, the outcome(s) of the action removes the motivating conditions, returning the protagonist to a "steady-state" story world, albeit one which has been altered by any outcome states. Subsequent episodes have as their starting point, or setting, this altered story world. If the initial action(s) does not remove the motivating conditions, several possibilities exist for the creation of subsequent episodes, and causal relationships between the episodes depend on the specific option pursued. For example, the goal might be abandoned and the problem left unresolved; a subgoal may be pursued and

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the goal returned to subsequently; or a different action sequence might be tried.

Previous empirical work indicates that *causal* cross-episode connections lead to better story memory than temporal connections (e.g., "Then") (Glenn, 1978) and that certain categories (structural types) of information within the episode are better recalled than others (e.g., Mandler & Johnson, 1977; Stein & Glenn, 1979). Other investigators have argued that it is not category that predicts memorability. Rather, causal relationship is important: Those events that have more direct causal relations with other events will be more readily retrieved than those that have weaker connections to other events (e.g., Graesser, 1981; Graesser, Robertson, & Anderson, 1981; Lehnert, 1978; Lichtenstein & Brewer, 1980; Trabasso, Secco, & van den Broek, 1984).

Recently, Trabasso and his colleagues (Trabasso & van den Broek, 1985; Trabasso et al., 1984) applied their causal chain analysis technique to a number of stories on which recall data had been collected by Stein and Glenn (1979). Three findings of Trabasso et al. (1984) are noteworthy: Level of recall of stories was linearly related to the proportion of events on the causal chain; (2) specific events that were on the causal chain were recalled better than those not on the causal chain; and (3) the number of direct connections that an event had to other events and the category of the event also predicted recall of that event, independent of whether it was on the causal chain. These findings led Trabasso and van den Broek (1985) to look at the unique contributions of (1) being on the causal chain, (2) number of connections, and (3) story category to the prediction of level of recall of story events in the Stein and Glenn (1979) data and in data collected by Omanson (1982). Using a three-factor model, they accounted for between 32 and 65% of the variance in probability of event recall in the Omanson (1982) and Stein and Glenn (1979) stories. The amount of variance accounted for was significantly reduced by removing any one of the three factors. At the same time, Trabasso and Sperry (1985) found that these three factors accounted for variation in importance judgments assigned to events in a corpus of stories that had been used by Brown and Smiley (1977).

However, across the three data sets, the relative importance of causal chain status as compared to number of connections varied, depending on the overall structure of the story. Causal chain status is a binary decision made for each story event. The number of connections an event has to other events and the identity of those events determine the overall network structure of the story. A linear causal chain exists when event connections exist only between adjacent story events. When events from one episode are causally connected to events in other episodes of the story, causal networks result. Trabasso and van den Broek (1985) concluded that the number of connections was more important for causal network stories in which events are "richly interconnected" through a number of cross-episode event connections.

As a result of their reanalyses, Trabasso and van den Broek (1985) proposed a recursive network model for capturing differences in narratives based on the casual or logical connections that pertain between episodes and between events across episodes. The network model uses story grammar categories to specify different types of events in an episode and allows the generation of various sorts of story structures by considering different types of cross-episode event relationships and the resulting networks. The recursive network model is impressive in its ability to systematically integrate a vast array of alternative accounts of what makes a narrative memorable and what makes some events more memorable than others. One aspect of memorability that has not yet been dealt with is a semantic one. In the recall studies and in the reanalyses conducted by Trabasso and van den Broek, structure and content have tended to covary.

In the present research, we were interested in the effects of causal structure on narrative recall for two types of structures in which the semantic content of the individual events was virtually identical. The two structures have different causal structures: The *sequential*[1] is a linear causal chain and the *embedded* a hierarchical causal network. In addition to controlling the event content, the story grammar category of events with similar content was the same across structures. Thus, the primary question for this research was the effect of the causal role of an event on its memorability. Our secondary purpose was to examine the nature of causal understanding for the two structures. A third issue was whether the effects observed for adults were also typical of children.

Recursive Network Model

The gist of the recursive network model (Trabasso & van den Broek, 1985) is the episode, a motivated action sequence comprised of the categories of information corresponding to those arising from previous analyses of episode structure (Mandler & Johnson, 1977; Rumelhart, 1975; Stein & Glenn, 1979). Trabasso and van den Broek present a convincing discussion of how a range of narrative structures may be generated from the recursive network model. Different structures depend most heavily on the semantic content and logical relations among three elements of the episode, the goal (G), the attempt (A), and the outcome (O). Sequential episode structures and linear causal chains rather than causal networks result when the outcome of an attempt is successful and the goal that motivated the attempt is no longer operative in the story world. A next episode may then occur. It is enabled by the story world conditions that result from the successful outcome of the prior episode but it is not necessarily caused by the events in the prior episode. That is, the outcome sets up the conditions that allow subsequent events to occur, which themselves lead to or cause new goals. In some forms of sequential structures the outcome may cause a new goal but the goals of the episodes are not causally related to one another. Thus, causal connections are restricted and occur between events that closely succeed and follow one another in the temporal presentation order of story events. An example of such a story, constructed specifically for this research, is given in Table 1.

The "Jimmy" story has three episodes. In the first Jimmy decides to get a job (5) and does. The outcome of the first episode (8 and 9) sets up the conditions for the occurrence of the first event in the second episode, (10 and 11). This event plus the goal of the second episode, wanting to save a lot of money (13), causes the attempt and outcome (14–17). The outcome of the second episode, having money, sets up the conditions for the third and final episode with its goal of wanting a bike like Tom's (21). Jimmy gets the bike (22–25) and the ending of the story is consistent with successful goal attainment. The linear causal chain for this story is shown schematically in Fig. 1a. Connections between event nodes are indicated by arrows. Each node is connected to the story node directly preceding it and directly following it. Only goal and outcome nodes have any noncontiguous connections.

In contrast to the sequential structure are embedded structures, containing hierarchical relations between episodes and generating causal networks of events rather than chains. The critical feature distinguishing an embedded structure from a successive is the relationship that holds among the goals of the story: If one goal remains active while other episodes occur then we may speak of an embedded or hierarchical

[1] Trabasso and van den Broek (1985) use the term successive where we use sequential. However, for consistency with previous discussions of these data (Goldman, 1985; Goldman & Varnhagen, 1981) we will use the term sequential.

TABLE 1
TEXT OF THE JIMMY STORY IN THE SEQUENTIAL AND EMBEDDED FORM

	Sequential structure	Node in Fig. 1a
1.	There once was a boy named Jimmy.	S
2 and 3.	One day Jimmy was talking to his mother. She said Jimmy could get a part-time job.	E_{11}
4.	Jimmy liked to work.	R_{11}
5.	He decided to get a paper route.	G_{11}
6 and 7.	He went to the newspaper office and talked to the sales manager.	A_{11}
8 and 9.	Jimmy got a list of customers and began to deliver newspapers.	O_{11}
10 and 11.	Jimmy met Tom along the route. Tom told Jimmy how to please the customers.	E_{12}
12.	Jimmy was interested in the idea.	R_{12}
13.	He wanted to save alot of money.	G_{12}
14 and 15.	He put the papers near each door and rang every doorbell.	A_{12}
16 and 17.	Jimmy earned alot of tips and saved all the money.	O_{12}
18 and 19.	Jimmy was taking the money to the bank and saw Tom's new bike.	E_{13}
20.	Jimmy thought the bike was neat.	R_{13}
21.	He wanted one like it.	G_{13}
22 and 23.	He counted his money and went to the bike shop.	A_{13}
24 and 25.	Jimmy picked out the bike he wanted and eagerly gave the man the money.	O_{13}
26 and 27.	Jimmy was very happy and rode the bike to Tom's house.	Rx
	Embedded structure	Node in Fig. 1b
1.	There once was a boy named Jimmy.	S
2 and 3.	One day Jimmy met Tom and saw Tom's new bike.	E_{11}
4.	Jimmy thought the bike was neat.	R_{11}
5.	He wanted one like it.	G_{11}
6 and 7.	He called the bike shop and asked about the price of bikes.	$A_{11} = E_{21}$
8.	Jimmy was still interested.	R_{21}
9.	He wanted to save money.	G_{21}
10 and 11.	He talked to his mother that night. She said Jimmy could get a part-time job.	$A_{21} = E_{31}$
12.	Jimmy liked to work.	R_{31}
13.	He decided to get a paper route.	G_{31}
14 and 15.	He went to the newspaper office and talked to the sales manager.	A_{31}
16 and 17.	Jimmy got a list of customers and began to deliver newspapers.	O_{31}
18 and 19.	He put the papers near each door and rang every doorbell.	A_{22}
20 and 21.	Jimmy earned alot of tips and saved all the money.	O_{21}
22 and 23.	Jimmy counted the money one day and went to the bike shop.	A_{12}
24 and 25.	Jimmy picked out the bike he wanted and gave the man the money.	O_{11}
26 and 27.	Jimmy was very happy and rode the bike to Tom's house.	Rx

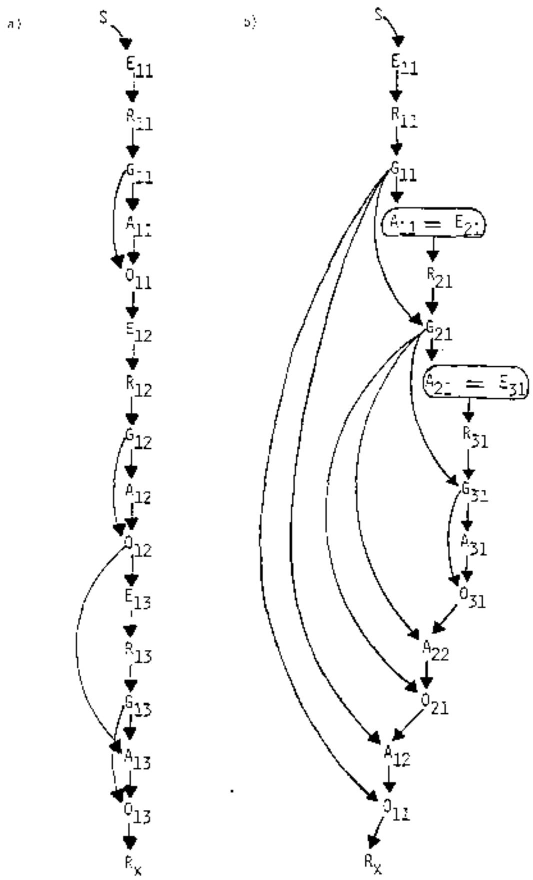


FIG. 1. Structure diagrams for (a) sequential causal chain stories and (b) embedded causal network stories.

structure and a causal network among events. Causal networks result from cross-episode connections between goals and from the noncontiguous presentation of goals and their goal-attaining events.

There are different forms of embedding. Trabasso and van den Broek (1985) distinguished between outcome- and goal-embedding. In outcome-embedding, events intervene between the multiple goals in the story whereas in goal-embedding an entire series of goals and subgoals is planned prior to any action being taken. In the goal-embedding case, it is as if the protagonist can foresee potential barriers and understand the prerequisites that must be met prior to being able to attain the highest order goal. In outcome-embedding, subgoals are generated during the actual problem solution and the need for subgoals emerges as the story unfolds. In both cases, the original goal remains operative while lower order subgoals are generated and attempts are made to meet these; successful attainment of the original and highest order goal must await successful outcomes for the lower order goals.

Using virtually identical semantic content, the events and states that were shown in the sequential structure were reorganized to form the embedded structure shown in Fig. 1b, the text of which is given in the second half of Table 1. In the embedded "Jimmy" story, the first goal is wanting a new bike like Tom's (5). The next event has a "double" function: It can be viewed as an attempt or as the first event in the second episode. Regardless of its' grammatical category this event causes the formulation of the goal of the second episode, wanting to save money (9). Similarly, the next event also has a "double" function and causes the goal of the third episode, deciding to get a job (13). The remainder of the story is a series of events that are attempts and outcomes associated with the three goals that have been formulated in the first half of the story. A critical aspect of the embedding is that the third goal (13) is attained prior to the attainment of the second; and the second prior to the first. However, with the attainment of each goal, Jimmy gets closer to being able to attain the highest order goal, getting the bike. Thus, the events that attain the most embedded goal (14–17) set up the conditions that permit the occurrence of the events that attain the next highest goal (9); similarly those that attain the second goal (18–21) set up the conditions for the occurrence of the events (22–25) that directly attain the bike goal.

Thus, using virtually identically worded events and story grammar categories, different structures were created: the sequential, having a causal event chain, and the embedded, having a causal event network. The primary research issue was the consequences of these differences for memory, assessed by a story recall task. Overall level of recall was expected to be similar since both structures have the same number of causal links and events on the causal chain. Predictions differ, however, for the pattern of node recall in the two structures. In the sequential, causal chain structure, event recall should be predicted by story category and number of causal links, consistent with previous findings of Trabasso and van den Broek (1985) and should be replicable regardless of whether stories are heard or read. In the embedded, causal network structure, the level in the hierarchy ought to also be an important predictor of event recall. Applicability of the predictions, derived from the recursive network model, to comprehenders of different ages was tested by conducting two experiments, one with college age adults and one with children.

A second issue of particular interest from a developmental perspective concerns the psychological validity of the postulated differences in the causal relationships among the story events, differences that give rise to the chain as compared to the network structure. To pursue this issue, we obtained causal explanations for selected story nodes. The focus was on the reasons for the protagonists' goals (why goal questions) and goal-attaining events (why attempt–outcome questions) because it is the causal connections related to these nodes that give rise to the chain as compared to network structures. We were particularly interested in whether children's explanations for the story events would reflect the goal hierarchy described in the embedded structure. In addition, Stein and Trabasso (1982) have reported that children sometimes violate the causal relations in a story world by explaining past behavior with future story events, attributing a type of precognizance to the protagonist. The presence of this tendency, particularly in the causal chain structure, was our focus.

Experiment 1

In addition to the issues outlined above, adult memory for the sequential and embedded structures was assessed immediately after presentation and at a delay of 48 h. The delay condition provided an assessment of the degree to which story category, number of connections, and level in the hierarchy maintain their relative importance to recall predictions over time.

Method

Subjects. Sixty-four college students fulfilling an introductory psychology course requirement participated. There were approximately equal numbers of males and females.

Design. The design was a split-plot factorial with two between-subjects factors and two within-subjects factors. Comprehension task (listening vs reading) and time of test (immediate vs delayed) were the between-subjects factors; structure (embedded vs sequential) and the story topic (Jimmy vs Sally) were the within-subjects factors.[2] There were 16 subjects in each of the four between-subjects cells. Order of presentation, structure, and story topic were counterbalanced across subjects in each cell.

Materials. In addition to the embedded and sequential structures for the "Jimmy" stories given in Table 1 and Fig. 1, we developed sequential and embedded "Sally" stories. In the sequential structure, Sally wants to buy crayons (G_{11}) and does; then she decides to make a candle (G_{12}) and does; finally, she wants to talk at show and tell in school (G_{13}) and talks about the candle. In the embedded structure, first Sally wants to talk at show and tell (G_{11}), then decides to make a candle to talk about (G_{21}), and then wants to get crayons for wax (G_{31}). She gets the crayons, makes the candle, and talks about it at show and tell.

[2] Both listening and reading were included to extend the generalizability of the results. Omanson's (1982) work was done on adults reading and Stein and Glenn's (1979) with fifth grade listeners.

Each of the four presentation stories contained 56 propositions (Turner & Greene, 1978) of which 27 were predicate propositions or statements consisting of a verb and its related arguments. The semantic content within the Sally set and within the Jimmy set was identical for 25 of the 27 statements. As illustrated in Table 1, each story contained three well-formed episodes, began with a one-statement setting, and ended with a two-statement reaction. Each story was tape recorded at a normal reading speed for use in the listening task and typed in a one-paragraph format for presentation in the reading task.

Six why questions for each story were written. Three asked "why goal?" and three asked "why attempt + outcome?" An example of a goal-node questions is "Why did Jimmy want a bike?" and of an attempt-outcome, "Why did Jimmy deliver newspapers and save his earnings?" The questions were typed and presented in booklet form in an order corresponding to order of appearance in the text. Approximately 3 in. of response space appeared below each question.

Procedure. Subjects were tested in small groups of 3–4 students. In the immediate listening condition, subjects listened to the tape recorded story after being told they would be asked to recall it. They worked on multiplication problems for 2 min and then wrote their recall and answered the why questions. Then they listened to the other story. The same procedure was used for the immediate reading group, except that they read the stories and these were removed prior to recall.

The delay groups were told to listen to or read each story once and that when they returned 48 h later they would be asked to recall each story and answer questions about them. When they returned, the recall and why question data were collected in the same way as described for the immediate groups. Subjects were not permitted to refer to their recalls when they answered the why questions.

Scoring. Recall protocols were scored for gist recall of each presented statement. Subjects frequently included statements that summarized across two to four presented statements but were not actually meaning preserving of any one presented statement. The gist recall measure credits the subject for recall of each statement encompassed by the summary and is thus a measure of number of statements recalled or summarized across.

A second measure of recall was computed to assess the pattern of node recall in the structures. In each episode there were five story category nodes. Of these, the E, A, and O nodes were represented by two statements each and the internal R and G nodes were each represented by one statement in each episode. Thus at the level of the nodes shown in Fig. 1, individual subjects could receive a 0, 1, or 2. A subject was credited with node recall if either 1 or 2 of the presented statements for that node were produced in recall.[3] Multiple regression techniques were used to evaluate the importance of story category, number of connections, and level in the network (for embedded structure only) in accounting for variance in node recall.

Responses to the why questions were scored as the gist of a statement from the text or as an inference and were analyzed in terms of the nodes and story categories shown in Fig. 1. An extensive and detailed discussion of these data appears in Goldman (1985). In the present context, primary interest is in the causal structure manifested by the patterns of responses. In particular, interest is in whether goals are explained by relatively contiguous information (e.g., the events and internal states directly preceding the goal), or more "dis-

[3] An individual subject could have recalled as few as 17 statements (setting plus one statement each for the remaining 16 nodes shown in Fig. 1) and still have produced a complete, well-structured causal chain or network. Thus, the *frequency* with which each node in the diagram in Fig. 1 was recalled provides a detailed picture of strength differences between nodes but does not describe differences between statements within nodes.

tant" information (e.g., other story goals, events, responses, and actions). For attempt–outcome responses interest was also in the relative contiguity of the responses.

Preliminary analyses of variance (ANOVAs) indicated that there were no differences between the patterns of effects observed for the Jimmy and the Sally topics. Therefore, the data were aggregated across the story topic factor and reanalyzed.

Results and Discussion

Recall. Gist recall scores for each subject (maximum = 27) were submitted to a two between- one within-factor split-plot ANOVA. The between-subjects factors consisted of comprehension task (listening or reading) and time of test (immediate or 48-h delay) and the within-subject factor was episode structure. The only significant effect was time of test, $F(1, 60) = 10.47$, $p < .01$. More was recalled at immediate test ($M = 21.84$ statements) than at the delayed test ($M = 16.25$), with this finding generalizing across both comprehension tasks. Thus, as expected, *overall* recall was not affected by the causal structure differences.

There were, however, differential patterns of node recall within each structure at each testing time and differential loss rates across testing time. Figure 2 gives the proportions of subjects who included each of the various nodes for the sequential causal chain.

According to predictions derived from the recursive network model, memorability of the nodes in the sequential structure should be affected by number of connections and story category. At immediate test, all nodes except the three goals and R_{12} were recalled by at least 75% of the students. The high levels of recall of the Es, As, and Os are consistent with previous findings (e.g., Mandler & Johnson, 1977) as well as with the predicted story

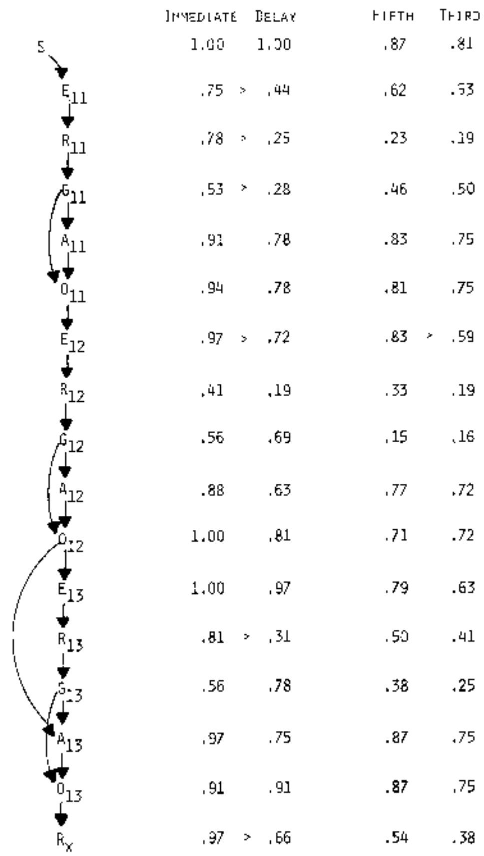


FIG. 2. Sequential causal chain: Proportion of individuals including each node in recall for Experiment 1 ($N = 32$ for immediate and for delay) and Experiment 2 ($N = 52$ in fifth grade and 32 in third grade). Inequality signs indicate significant differences, $z > 2.35$, $p < .01$.

category effect. Recall of each of the three goals was equivalent, Cochran's $Q = 0.09$, consistent with the equivalent number of connections for each goal. The pattern for the delayed group revealed a significant loss of information from the beginning portion of the story (nodes E_{11}, R_{11}, and G_{11}) and for the other two internal R nodes. However, goal recall presented a curious phenomenon: Contrary to the lower level of recall overall and for most of the other nodes, G_{12} and G_{13} are included more frequently at delay than at immediate recall, and these two goals are recalled signifi-

TABLE 2
REGRESSION MODELS FOR PREDICTING NODE RECALL AT IMMEDIATE AND DELAYED TESTS[a]

	R^2		Predictor				
	Exp.	Obs.	Event + Attempt + Outcome vs Goal + Response	Event vs Attempt + Outcome	Goal vs Response	Number of connections	Levels
Sequential chain							
Immediate							
Model 1[b]	.10	.60	sss	ns	ns	—[c]	—
Model 2	.14	.63	ss	ns	ss	ns	—
Delay							
Model 1	.10	.60	sss	ns	sss	—	—
Model 2[b]	.14	.68	sss	ns	ns	ss	—
Embedded network							
Immediate							
Model 1	.10	.45	sss	ns	ns	—	—
Model 2	.14	.60	sss	ns	sss	sss	—
Model 2′	.14	.60	sss	ns	ns	—	sss
Model 3[b]	.17	.66	sss	ns	ss	ss	ss
Delay							
Model 1	.10	.45	sss	ss	ss	—	—
Model 2	.14	.51	sss	ss	ns	s	—
Model 2′[b]	.14	.55	sss	ss	ss	—	ss
Model 3	.17	.57	sss	ss	ns	ns	s

[a] Expected values are the R^2s one would expect even if there were no relationship between the predicted and predictor variables, given the number of observations predicted and the number of predictors. One of the story category contrast predictors is not shown since it was never a significant predictor, the Attempt versus Outcome contrast. Thirty data points were predicted: Frequency of recalling 15 nodes in the Jimmy and 15 nodes in the Sally story. All observed R^2 values are significant at the $p < .01$ level. Significance levels of the predictors are indicated by sss ($p < .01$), ss ($p < .05$), s ($p < .1$), and ns ($p > .1$). The same models were used to predict 48 data points: Frequency of recalling 24 statements in Jimmy and 24 in Sally. R^2 values ranged from .15 to .34 and the patterns of significance for the model fits and predictors were similar to those reported here.

[b] Indicates the best fitting model in each group for each structure.

[c] Indicates that the model for that row does not include the predictor named by the column.

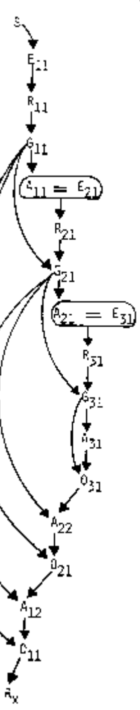
cantly more often than G_{11}, Cochran's $Q = 18.9$, $p < .01$, post hoc critical difference between proportions = .29. Finally, at delay, recall levels of outcomes remained above 75%. Thus, the overall mean decline in recall from immediate to delay of approximately 20% can be accounted for by specific nodes and does not reflect a uniform loss.

Multiple regression techniques were used to statistically examine the contributions of story category and number of connections to accounting for the obtained patterns of node recall. Number of connections, a continuous variable with range 1–5 and mean 2.68, and story category (excluding S and Rx) were used to predict frequency of node recall in each of the two story topics (30 nodes altogether). Story category was treated as a dichotomous variable and entered as four "dummy" variables representing a set of four orthogonal contrasts among the five categories comprising an episode.[4] Table 2 shows the results. Significant R^2s were obtained for two models at each recall time. Model 1, story category, accounted for 60% of the variance in node recall at immediate and at delayed tests. Adding connections created significant improvement in the fit (Model 2) only for delayed recall. The significant story category variable at immediate reflects the previously described and clearly visible pattern in Fig. 2, namely the [E + A + O] versus [G + R] contrast. At delay, this contrast plus number of connections was the significant predictor under the best fitting model, Model 2. The greater impor-

[4] The four dummy variables represented the following contrasts: [E + A + O] versus [G − R], G versus R, E versus [A + O], and A versus O.

tance of number of connections at delay than at immediate is consistent with a tendency observed by Trabasso and van den Broek (1985) in their reanalysis of Omanson's data.

For the embedded causal network structure, predictions derived from the recursive network model are that in addition to story category and number of connections, the level of a node in the network will also be an important predictor of recall. Figure 3 gives the frequency of node recall for the embedded structure. At immediate recall, all nodes except R_{21}, R_{31}, G_{21}, and G_{31} were recalled by 84% (26 of 32) or more of the subjects. Furthermore, the frequency of recalling the G nodes differed in a manner consistent with both the level and number of connections variables: G_{11} (84%) and G_{21} (69%) were included equally often and each was included more frequently than G_{31} (25%), Cochran's $Q = 22.38$, $p < .01$, post hoc critical difference = .31. G_{31}, recalled by only 8 of 32 subjects, has the fewest connections to other nodes (4) and is also at the lowest level in the hierarchy. G_{11} is at the topmost level and has five connections and G_{21}, at the second level, has six connections. In contrast to the pattern in the sequential chain structures but as predicted by the recursive network model, goal recall in embedded causal network structures was affected by level and number of connections at immediate test.



Node	Immediate		Delay	Fifth		Third
S	1.00		1.00	1.00		.91
E_{11}	.97	>	.75	.92	>	.69
R_{11}	.94	>	.72	.71		.53
G_{11}	.84		.31	.60		.50
$A_{11} = E_{21}$	.88	>	.41	.52		.31
R_{21}	.53	>	.00	[illegible]		.05
G_{21}	.69		.56	.36		.25
$A_{21} = E_{31}$	.91	>	.53	.83		.75
R_{31}	.50	>	.09	.27		.36
G_{31}	.25		.28	.19		.15
A_{31}	1.00		.91	.83		.72
O_{31}	.88		.88	.73		.72
A_{22}	1.00		.84	.77		.65
O_{21}	.91		.84	.73		.59
A_{12}	.94		.75	.79		.56
C_{11}	.91		.81	.77		.78
R_x	.97		.84	.63		.56

FIG. 3. Embedded causal chain: Proportion of individuals including each node in recall for Experiment 1 ($N = 32$ for immediate and for delay) and for Experiment 2 ($N = 52$ in fifth grade and 32 in third grade). Inequality signs indicate significant differences, $z > 2.35$, $p < .01$.

At delayed test, the goal pattern was identical to that at immediate *and* the frequencies of goal node inclusion were virtually identical at the two testing times. At delay, G_{11} (81%) and G_{21} (66%) were included equally often and each was included more often than G_{31} (28%), Cochran's $Q = 16.36$, $p < .01$, post hoc critical value = .32. The nodes that showed the greatest differences at the two testing times were the Es and Rs in the two embedded episodes. It is interesting to note that despite the "double" function of $A_{11} = E_{21}$ and $A_{21} = E_{31}$, these nodes were among the least well recalled at the delayed testing time.

The multiple regression analyses on the embedded structure recall data included the continuous "levels" variable (range 1–3) in addition to the number of connections (range 1–7) and the four-variable story category predictor. Four models were fit to the data and significant R^2 values were obtained for each model at each testing time, as can be seen in the lower portion of Table 2. Model 1, the four-contrast story category variable, accounted for 45% of the variance in node recall. For immediate recall, including either connections (Model 2) or levels (Model 2′) increased the R^2 value by the same amount, .15. Including all three variables raised the R^2 an additional .06 to .66. Each of these predictors was significantly nonzero at immediate test. Furthermore, the relationship of the four models in terms of the predictors is orderly and additive: The contrast between categories associated with external events and actions and those associated with internal states and cognitions accounted for significant variance; adding number of connections improved the fit and then adding levels improved the fit still further. Thus, embedded node recall at immediate test is entirely consistent with predictions of the recursive network model.

The picture at delayed recall is a bit more complex. From the basic Model 1 R^2 = .45, Model 2′ increased the R^2 values more, and more systematically than Model 2. Adding connections to Model 2′ did not increase the R^2 more than would be expected by adding any other additional predictor. (Refer to the column "expected" in Table 2.) This is consistent with the fact that in the Model 3 solution, the connections parameter was not significantly different from zero whereas the levels parameter was. For this embedded causal network, Model 2′ appears to give the best account of the variance in node recall at delayed test. This model takes into consideration the level in the goal hierarchy plus three of the story category contrasts, including the G versus R contrast.

Thus for the embedded causal network structure, story category, number of connections, and levels are important in accounting for variance in node recall at immediate test. At delay, variance in node recall can be accounted for without number of connections if the level of a node in the network is included as a predictor variable. For sequential causal chain structures where the nodes do not vary in terms of level, category, and number of connections are needed to account for the variance at delay but only category is needed at immediate.

These findings are basically consistent with those of Trabasso and van den Broek (1985) and extend them in several important ways. The present data indicate the locus of the importance of story category. For both structures at both testing times, the best models included the contrast of external events and action categories (E, A, O) with internal cognitive events and states (R, G). Nothing beyond this contrast was needed to account for node recall from a sequential causal chain at immediate test. The best model for delay sequential added in the number of connections. Adding still further the G–R contrast and levels, we arrive at the best model for immediate embedded causal network recall. Delayed recall for the causal network did not include connections but did include an additional story category contrast and levels.[5] Finally, we point to the findings regarding the G nodes: The patterns predicted by the recursive network model were observed for both causal structures at immediate test. The delayed test G recall levels were somewhat unexpected in both structures. In the causal chain the goals later in the story tended to be recalled at higher levels than at immediate test, a surprising finding given the generally lower level of recall at delay. In the causal network goal nodes were recalled at levels identical to immediate recall and at levels entirely consistent with predictions from the recursive network model.

Why questions. Of primary interest in the why question data were the type and proximity of the information given in response to the three why goal and three why (attempt + outcome) questions for each structure. In the sequential, causal chain structure each of the goal nodes is caused by the E and R nodes directly preceding it, as can be seen in Fig. 1. The prediction was that responses to each of the "why goal" questions would be one of these two nodes. The data in Table 3 indicate that this prediction was confirmed in both groups of subjects for two of the goals, namely G_{13}

[5] We suspect that the role of number of connections at delay is masked by the entry of levels and the E versus [A + O] and G versus R contrasts, significant category contrasts in the Model 2′ solution.

TABLE 3
WHY QUESTION RESPONSES FOR ADULTS[a]

Response nodes	Questioned nodes: $Goal_{11}$ Imm	$Goal_{11}$ Del	$Attempt_{11}$ + $Outc_{11}$ Imm	$Attempt_{11}$ + $Outc_{11}$ Del	$Goal_{12}$	$Attempt_{12}$ + $Outc_{12}$	$Goal_{13}$	$Attempt_{13}$ + $Outc_{13}$
Sequential structure								
$Event_{11}$ or $Response_{11}$	**.59** >	.19	.30	.28				
$Goal_{11}$	*	*	**.63**	**.41**				
$Attempt_{11}$ + $Outcome_{11}$			*	*				
$Event_{12}$ or $Response_{12}$					**.57**	**.47**		
$Goal_{12}$	.13	**.31**[b]		.28	*	.23		
$Attempt_{12}$ + $Outcome_{12}$						*		
$Event_{13}$ or $Response_{13}$							**.93**	**.59**
$Goal_{12}$					.12		*	.36
$Attempt_{13}$ + $Outcome_{13}$								*
Inferred goals	.28	**.47**			.29			

Response nodes	Questioned nodes: $Goal_{11}$	$Goal_{21}$	$Goal_{31}$	$Attempt_{32}$ + $Outc_{31}$	$Attempt_{22}$ + $Outc_{21}$	$Attempt_{12}$ + $Outc_{11}$
Embedded structure						
$Event_{11}$ or $Response_{11}$	**.75**					.16
$Goal_{11}$	*	**.54**			**.61**	**.59**
$Event_{21}$ or $Response_{21}$		.34				
$Goal_{21}$		*	**.68**	**.50**	.29	
$Event_{31}$ or $Response_{31}$			.14	.11		
$Goal_{31}$			*	.22		
$Attempt_{32}$ + $Outcome_{31}$				*		
$Attempt_{22}$ + $Outcome_{21}$					*	
$Attempt_{12}$ + $Outcome_{11}$						*
Inferred goals	.12					.18

[a] Relational sign (>) signifies a significant difference between proportions as evaluated by a z-score test of differences between proportions, $p < .01$, two-tailed, critical value $z > 2.35$. Immediate (Imm) and delay (Del) are listed separately only for the two questions where different patterns of responses occurred. *Indicates the location of the questioned nodes relative to the response nodes given in the leftmost column. Only proportions significantly greater than zero are reported, $zs > 2.35$. Dominant responses in each column are in boldface.

[b] .47 = .31 but each is >.19.

and G_{12}, and in the immediate test group for G_{11}. At delay, G_{11} was explained by goal responses significantly more often than by the predicted response nodes. Either G_{12}, the second episode goal in the presented story, or an inferred goal was given. In both cases, the effect of these goal responses is to make G_{11} function as a subgoal, similar to the goal relationships in the embedded structure.

Based on the causal chain, the predictions for the A + O node responses are the G nodes directly preceding them. The data in Table 3 again confirmed this prediction in all cases except the A_{11} + O_{11} node at delay. Explanations for the A_{11} + O_{11} node were prior nodes 70% of the time, but G_{12} was provided as an explanation in a substantial number of cases (0.28), consistent with the functional embedding that occurred for G_{11} at delay. Thus over a delay, subjects had a tendency to convert the causal chain structure in the first two episodes into a more embedded network structure. This pattern is also an example of forward inference in that an event is explained by one that has not yet occurred.

In the embedded causal network, structural and conceptual proximity lead to different predictions for all questioned nodes except G_{11}, the highest order goal in the story. For G_{11}, the prediction is the same as in a sequential causal chain, namely E_{11} or R_{11}, the conceptually *and* structurally most proximal causes. This prediction was confirmed, as the data in the second half of

Table 3 indicate: 75% of the responses were E_{11} or R_{11}. For the other two goals, E and R are the structurally proximal causes but the goal from the embedding episode functions as a cause also, and has conceptual proximity. The data in Table 3 indicate that for all subjects the dominant responses to G_{21} and G_{31} are the conceptually proximal nodes, G_{11} and G_{21}, respectively. Thus, the plan or problem solution that generates the network structure and the levels in the goal hierarchy is reflected in the causal explanations. The structurally closer nodes are relatively weak explanatory responses. This is not merely a failure to remember E_{21} or E_{31} since the response pattern is prevalent in immediate test subjects who recalled these nodes approximately 90% of the time. The responses to the A + O nodes also reflect the subgoal problem-solving structure of the embedded causal network: The dominant response to each A + O node is the closest goal node that remains *unmet*. Thus, rather than explaining A_{32} + O_{31} by the structurally closest nodes (E_{31}, R_{31}, or G_{31}), half the subjects indicated that these action and outcome events occurred because of the active status of G_{21}. The same tendency was observed for A_{22} + O_{21} explanation, with only 30% being the goal at the same level.

Thus, explanations for both goal and attempt + outcome nodes in an embedded structure reflected functional or conceptual proximity relationships more strongly than structural proximity relationships. The recall patterns and why questions provided evidence of the psychological validity of the distinctions in the two structures for adults. Their validity for children was examined in Experiment 2.

Experiment 2

The purposes of our investigation of children's recall and question-answering behaviors were to examine developmental similarities and differences in the factors affecting information recall and in the causal explanations of goals and goal-attaining events. The study included the age group (fifth graders) and task (listening) examined by Trabasso and van den Broek (1985) plus a younger group (third graders) and a reading task.

Method

Subjects. Thirty-two third (mean age 8.71 years) and 52 fifth (mean age 10.73 years) grade children from a Southern California public school district participated. There were approximately equal numbers of boys and girls.[6]

Design. The design was a split-plot factorial with two between-subjects factors, grade (third vs fifth) and comprehension task, and one within-subjects factor, structure. Twenty third graders and 28 fifth graders listened to the stories; 12 third graders and 24 fifth graders read the stories. Order of presentation of episode structure and story topic were counterbalanced across subjects in each between-subject cell.

Materials. Materials were the same as those used in Experiment 1.

Procedure. Subjects were tested individually. In the listening condition, subjects listened to the tape-recorded text; in the reading condition, subjects read the typed one-paragraph text. Subjects were told to listen to or read the text very carefully because they would be asked to recall it. Immediately after text presentation, subjects counted backward from 30 to counteract any short-term memory effects and then recalled the text and answered the why questions. The procedure was then repeated for the second text. All responses were tape recorded and later transcribed.

Scoring. Recall and why question responses were scored according to the pro-

[6] Students were originally grouped as average and below average readers based on district reading comprehension test scores. Preliminary analyses indicated that there were no differences in patterns of effects due to reading ability; as a result, the data from average and below average readers were aggregated and reanalyzed.

cedures described in Experiment 1. As with the adult data preliminary ANOVAs indicated no story topic or presentation order effects and were reanalyzed across these factors.

Results and Discussion

Recall. Gist recall scores were submitted to a two between-one within-factor split-plot ANOVA. Between-subjects factors consisted of grade and comprehension task and the within factor was episode structure. There was a significant main effect of grade, $F(1, 80) = 12.99$, $p < .01$: Fifth graders ($M = 15.34$) recalled more than third graders ($M = 12.72$). There were no main effects of task nor structure and no interactions were significant.

Although fifth graders recalled more than third graders, the patterns of node recall within each grade were similar. According to predictions derived from the recursive network model for the sequential causal chain, memory should be predicted by story category and number of connections. As the frequency data in Fig. 2 show, there is a category effect in each grade: A and O nodes are included at consistently high levels (minimum = 72%); Rs and Gs are least well recalled. Contradicting the model but consistent with the adult delay results, goal inclusion varied. Among the fifth graders, G_{11} (0.46) and G_{13} (0.38) were included equally often and more frequently than G_{12} (0.15), Cochran's $Q = 13$, $p < .01$, post hoc critical difference = .21. In third graders, G_{11} (0.5) was included more often than G_{12} (0.16), which was included as often as G_{13} (0.25), Cochran's $Q = 8.43$, $p < .05$, post hoc critical difference = .29.

The importance of the category effect in predicting recall was confirmed by the multiple regression analyses for each grade, as reported in Table 4. The best model was

TABLE 4
REGRESSION MODELS FOR PREDICTING NODE RECALL BY FIFTH AND THIRD GRADERS[a]

	R^2		Predictor				
	Exp.	Obs.	Event + Attempt + Outcome vs Goal + Response	Event vs Attempt + Outcome	Goal vs Response	Number of connections	Levels
Sequential chain							
Fifth graders							
Model 1*	.10	.63	sss	ns	ns	—	—
Model 2	.14	.64	sss	ns	ns	ns	—
Third graders							
Model 1*	.10	.66	sss	ns	ns	—	—
Model 2	.14	.66	sss	s	ns	ns	—
Embedded network							
Fifth graders							
Model 1	.10	.53	sss	ns	ns	—	—
Model 2	.14	.54	sss	ns	ns	ns	—
Model 2′*	.14	.64	sss	ns	ns	—	sss
Model 3	.17	.64	sss	ns	ns	ns	ss
Third graders							
Model 1*	.10	.44	sss	ns	ns	—	—
Model 2	.14	.44	sss	ns	ns	ns	—
Model 2′	.14	.45	sss	ns	ns	—	ns
Model 3	.17	.46	sss	ns	ns	ns	ns

[a] Expected values are the R^2s one would expect even if there were no relationship between the predicted and predictor variables, given the number of observations predicted and the number of predictors. One of the story category contrast predictors is not shown since it was never a significant predictor, the Attempt versus Outcome contrast. *Indicates the best fitting model in each group for each structure. —Indicates that the model for that row does not include the predictor named by the column. Thirty data points were predicted: Frequency of recalling 15 nodes in the Jimmy and 15 nodes in the Sally story. All observed R^2 values are significant at the $p < .01$ level. Significance levels of the predictors are indicated by sss ($p < .01$), ss ($p < .05$), s ($p < .1$), and ns ($p > .1$). The same models were used to predict 48 data points: Frequency of recalling 24 statements in Jimmy and 24 in Sally. For the sequential case, Model 1 also provided the best and significant fits in each grade (R^2s of .29 and .37 in the third and fifth grades). For statement recall in the embedded structure, Model 1 provided the best fit in third grade ($R^2 = .19$, $p = .05$) and Model 2′ in the fifth grade ($R^2 = .24$, $p = .05$).

Model 1 and it accounted for 63 and 66% of the variance in fifth and third grades, respectively. Thus, as found for the adult immediate group, in both fifth and third grades, number of connections was not a significant predictor of recall. What was important was the [E + A + O] versus [G + R] contrast.

According to the recursive network model, variance in recall of the nodes in the embedded causal network structure should be predicted by level in the hierarchy in addition to story category and number of connections. Generally, these predictions were confirmed in the fifth graders. The frequency of node recall data for this group (see Fig. 3) indicated better than 70% recall for all A and O nodes and for the topmost E and R nodes. Furthermore, the G nodes showed a systematic decline from the topmost goal, $G_{11} = 0.6$, to the lowest, $G_{31} = 0.19$, Cochran's $Q = 15.76$, $p < .01$, post hoc critical difference = .24. However, as reported in Table 4, multiple regression indicated that the best model for the fifth graders was Model 2′, the category plus level in the goal hierarchy model. Variance due to connections (after category is taken into account) appears to be a subset of that due to levels. The fifth graders and adults tested at delay were fit by the same model. The third graders replicated the goal pattern of the fifth graders, Cochran's $Q = 10.21$, $p < .01$, post hoc critical difference = .27. However, as shown in Table 4, the variance in node recall was predicted by Model 1, and the only significant predictor was the category contrast [E + A + O] versus [G + R]. Interesting too is the generally poorer fit of any of these models to the third grade data. An alternative model is not obvious since a simple serial position effect would be contradicted by the high level of inclusion of E_{31} and R_{31} as compared to E_{21} and R_{21}.

Although the recursive network model emphasizes the key role that the goal plays in determining overall causal structure, goals were not central in the recall protocols. The why question data examine further the children's understanding of causal relationships among events.

Why questions. The distribution of answers to the why questions into the various response nodes is given in Table 5, combined across grade levels since there were no significant differences between proportions occurring at each response node. As discussed in the presentation of the adult data, in the sequential structure, explanations for goals were expected to be the immediately preceding E or R nodes. Only for G_{13} was the dominant response consistent with this prediction. Responses for the other two goals had the effect of embedding the questioned goal node in another goal. For G_{11}, the dominant response was an inferred goal (0.45) and about one-third of the responses were G_{12}, the goal of the second episode in the story. For G_{12} there was no dominant response; rather one-third were the next goal, G_{13}, one-third an inferred goal, and only one-third were the predicted nodes.

Similarly, predictions for A + O node explanations (prior E, R, or G nodes) were confirmed only for responses in the third episode, that is, for $A_{13} + O_{13}$. For the first and second episode A + O nodes, there was a tendency to respond with G nodes that occurred subsequently, that is, in the next episode. Thus, the why question data indicate the forward inference tendency noted by Stein and Trabasso (1982). Such forward inferences may be functional aids to memory and or comprehension. These inferences create additional causal connections that alter the chain structure and create more of a causal network. Forward inferences may be a mnemonic or a production strategy engaged in only under circumstances where a sequential causal chain becomes lengthy.

The responses to the six why questions in the embedded structure replicated the adult data. As shown in Table 5, for G_{31} and G_{21}, the conceptually proximal response, the G node "one level up," was the domi-

TABLE 5
WHY QUESTION RESPONSES FOR FIFTH AND THIRD GRADERS[a]

	Questioned nodes					
Response nodes	$Goal_{11}$	$Attempt_{11}$ + $Outc_{11}$	$Goal_{12}$	$Attempt_{12}$ + $Outc_{12}$	$Goal_{13}$	$Attempt_{13}$ + $Outc_{13}$
Sequential structure						
$Event_{11}$ or $Response_{11}$	.23	.19				
$Goal_{11}$	*	**.54**				
$Attempt_{11}$ + $Outcome_{11}$		*				
$Event_{12}$ or $Response_{12}$			.33	.26		
$Goal_{12}$	.28	.21	*	**.37**		
$Attempt_{12}$ + $Outcome_{12}$				*	.15	.09
$Event_{13}$ or $Response_{13}$					**.70**	.37
$Goal_{13}$			.39	.34	*	**.44**
$Attempt_{13}$ + $Outcome_{13}$						*
Inferred goals	**.45**		.27		.08	

	Questioned nodes					
	$Goal_{11}$	$Goal_{21}$	$Goal_{31}$	$Attempt_{32}$ + $Outcome_{31}$	$Attempt_{22}$ + $Outcome_{21}$	$Attempt_{12}$ + $Outcome_{11}$
Embedded structure						
$Event_{11}$ or $Response_{11}$	**.71**					.11
$Goal_{11}$	*	**.70**		.07	**.68**	**.75**
$Event_{21}$ or $Response_{21}$		.17				
$Goal_{21}$		*	**.55**	**.58**	.26	
$Event_{31}$ or $Response_{31}$			.32	.15		
$Goal_{31}$			*	.18		
$Attempt_{32}$ + $Outcome_{31}$				*		
$Attempt_{22}$ + $Outcome_{21}$					*	
$Attempt_{12}$ + $Outcome_{11}$						*
Inferred goals	.22					.11

[a] Proportions are reported for all children since there were no significant grade differences between proportions for each cell in the table, $z < 2.35$. Dominant responses in each column are in boldface and are significantly greater than the other proportions in the column, $zs > 2.35$, $p < .01$. *Indicates the location of the questioned node relative to the response nodes given in the leftmost column. Only proportions significantly greater than zero are reported, $z > 2.35$.

nant response. For G_{11}, where conceptual and structural causes are the same nodes, 71% of the explanations were those nodes, namely E_{11} or R_{11}. Conceptual proximity also dominated in the responses to each of the A + O node questions. Responses were goals for the most part, but the G node tended to be one level up in the goal hierarchy.

The causal representations inferred from the patterns of responses to the why questions, including the tendency to create embedding causal links in the sequential chain, suggest that the embedded causal network may be developmentally easier to understand, remember, and/or use as a retrieval scheme. The present experiment cannot disentangle these possibilities. Furthermore, the differences between strength of the G nodes in why questions responses, compared to their strength in the story recall protocols, suggest that children's production rules for retelling a story may assume a natural inference of the following type: A goal may be inferred by the audience from attempts and outcomes in which it is attained and it is not necessary to include it, unless it is high in a goal hierarchy.

GENERAL DISCUSSION

The structural differences between causal chain and causal network were reflected in the causal explanations and in the recall of both adults and children. Because the sentence by sentence content was largely the same, the effects of chain versus network cannot be accounted for by semantic differences between the texts, at least at the sentence level. In dealing with the embedded causal network structure, children's and adults' explanations tended to stress the topmost goal and explain actions with respect to remaining outstanding goals. For the sequential causal chain the tendency was to partially convert the causal chain to more of a network. This tendency was stronger in the children's responses than in the adults and appeared to increase as processing difficulty of the task increased (see Goldman, 1985, for further discussion of this point). These sorts of responses are forward inferences and they may be a functional and practical strategy for easing demands on the memory system.

The recall results are generally consistent with predictions derived from the recursive network model and illustrate its applicability to listening and reading for adults and fifth and third graders. The most important predictor of children's recall of a sequential structure in which all information is on the causal chain was the story category contrast of observable events and actions with internal ones. There was also a tendency in both grades to recall the first mentioned goal (G_{11}) more often than the others, even though the three were at the same structural level. This is not a semantic effect since in the embedded structure, G_{31}, the semantic equivalent of sequential G_{11} was the least well-recalled goal. The children, then, replicate the adults at immediate in terms of the category effect but differ from both adult groups in terms of their memory for the episode goals. For the embedded structure, the adult immediate recall data were fit by the most complex model but the best fit for the youngest children's data was the simplest model. The fifth graders' recall behavior was accounted for by the same two variables as the adult delay test group: levels and observable versus internal story categories. It appears that for the embedded causal network, connection is less important than level. Patterns of goal recall were similar across all subjects and predicted by level in the embedded causal network: Recall was best for the topmost goal and worst for the most embedded one.

Finally, the goals were given as causal explanations far more often than would have been expected on the basis of their inclusion in recall. One possibility as to why concerns the redundancy relationships between different sorts of information comprising an episode and story. If a goal has been attained and this outcome has been included in the recall, the recaller may edit out the goal statement since it can be inferred from the outcome and any reaction to the outcome. It may be that goals as well as the outcomes from which they could be inferred are more likely to be included if a lengthy plan or subgoal sequence has been executed. Inclusion of both may also be a function of the reteller's understanding of the audience and of the task demands. It is not hard to imagine a context in which the pragmatically appropriate strategy is to err by saying too much, rather than too little.

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