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Causal Thinking and the Representation of Narrative Events

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The basis for representing narrative events in memory was investigated in reanalyses of the stories and data of R. C. Omanson (1982b, *Journal of Verbal Learning and Verbal Behavior*, **21**, 326–337) and N. L. Stein and C. G. Glenn (1979, In *New Directions in Discourse Processing*. Hillsdale, NJ, Erlbaum). Causal network representations of the stories were derived for prediction of data on immediate and delayed recall, summarization, and judged importance of events. Properties of the networks were compared in multiple regression analyses with other factors, notably the story-grammar categories of the events. Whether or not an event was in a causal chain and the number of its causal connections were both found to account for substantial proportions of common and unique variance in all four measures. The story-grammar category of events also contributed unique variance but overlapped substantially with the causal factors. The concreteness, serial position, and argument overlap of an event failed to account uniquely for the data. A recursive transition network model is discussed that integrates story grammar, causal chain, causal network, and hierarchical problem-solving approaches to story representation.

Early investigations of story comprehension focused on the retelling of a story as a measure of understanding (Binet & Henri, 1894; Bartlett, 1932). The use of memory as a measure of language comprehension, in general, and story comprehension, in particular, has continued into modern times (e.g., Mandler & Johnson, 1977; Stein & Glenn, 1979; Thorndyke, 1977). Throughout, a consistent finding is that some narrative events are more memorable than others. Specifically, events that are best recalled introduce the protagonist(s) and/or provide a temporal–spatial context in which the story occurs, initiate goal states within the protagonist, express the major goal of the protagonist, and describe the consequences of the protagonist's goal-directed action. Those less well recalled provide more detailed background information, describe subordinate goals, actions, other internal states or reactions of the protagonist to the consequences, and other detail (Mandler & Johnson, 1977; Mandler, Scribner, Cole, & DeForest, 1980; Nezworski, Stein, & Trabasso, 1981; Omanson, 1982b; Stein & Glenn, 1979).

Why are particular story events recalled more frequently than others? Although events vary in multiple ways, existing interpretations selectively emphasize single properties. One such interpretation is that events that have organizational functions are more memorable than others. These functions are categorical in nature and episodic in organization. For example, in the

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Stein and Glenn (1979) "story grammar," the events in an episode are labeled, in sequence: settings, initiating events, internal states (including goals, cognitions, and emotions), attempts, consequences, and reactions (including emotions, cognitions, and actions). Of these, settings, initiating events, goals, and consequences are found to be consistently better recalled (e.g., Mandler & Johnson, 1977; Stein & Glenn, 1979). While these categories reflect content and story-function roles, the events they classify are successively linked in the grammars by causal and temporal relations.

Another view focuses on the dependencies between the concepts which underlie the statements depicting the events rather than on the event classifications or functions. Here, events that can be ordered into a causal sequence through the story are best recalled. Events that are not in this sequence lack coherence, are "pruned" or edited from the chain (Schank, 1975), and are thus less well recalled (Black & Bower, 1980; Lehnert, 1978; Omanson, 1982a, 1982b; Schank, 1975; Trabasso, Secco, & van den Broek, 1984; Warren, Nicholas, & Trabasso, 1979).

A near position assumes that events are causally related but are organized as networks. Events that have several, direct causal relations with other events are more readily retrieved than those with fewer dependencies (Graesser, 1981; Graesser, Robertson, & Anderson, 1981; Lehnert, 1978; Trabasso et al., 1984).

In this brief synopsis, three factors have been identified which predict the memorability of particular events: (1) the story-grammar category of the event, (2) the presence or absence of the event in a causal chain, and (3) the number of relations an event has to other events. In response to the recognition that story events are multivariate in nature, three studies on recall, involving identification of causal relations (Black & Bower, 1980; Omanson, 1982b; Trabasso et al., 1984), have made relative comparisons of two or more of these factors.

Omanson (1982b) used a causal analysis (described in Omanson, 1982a) to identify events in the causal sequences that ran through the story. For him, "central" events are those that are both causal and purposeful; "noncentral" events do not have consequences that are part of the sequence leading to the end of the story. Not only were central events more often recalled but they were also more frequently summarized and judged as more important than noncentral events. Of interest here is Omanson's comparison of the effect of centrality with the categorical nature of events in terms of the proportions of variance accounted for by these factors (ω^2). Centrality was claimed to be superior to the category factor because the proportion accounted for by the categories dropped nearly 75% after centrality was factored out.

Black and Bower (1980) intuitively identified causal relations among statements and ordered strings of statements into hierarchically arranged episodes. Statements were assigned a "critical path" status if they were causal and purposeful. The latter meant that the actions resulted in goal attainment. Events not in the critical path consisted of those events in chains that did not lead to goal attainment or that contained "detail." The critical path, story-grammar categories, and hierarchial representations (Kintsch, 1975; Rumelhart, 1977) were compared in step-wise regression. This procedure showed that the critical path factor was the best individual predictor with the hierarchical level second.

In the Omanson and in the Black and Bower analyses, temporal succession characterizes the causal sequences. As such, the linear structure precludes causal connectivity as a separate factor. Connectivity may be involved because of the possibility of multiple relations of one event, for example a goal may motivate several actions and thus have multiple, causal connections. By definition, causal chain events, with the exception of some setting or consequence statements, must have at least two causal connections, an antecedent and a conse-

quent. Events not in the sequence may have only one or no connections. One would thus expect that the causal sequence, as a factor, would covary to some extent with causal connectivity of events. Causal inferences that transcend the constraints of a linear, temporal sequence (Trabasso & Sperry, 1985) would also increase the number of an event's relations, particularly for settings, goals, and consequences.

Trabasso and Sperry (1985) reanalysed six stories used by Brown and Smiley (1977) in judgments of importance of events to the story as a whole. In multiple regression, Trabasso and Sperry found that connectivity accounted for substantial proportions of unique variance as well as common variance with the causal chain factor; the causal chain did not account for any significant unique variance. These data support the idea that networks rather than linear chains are a better characterization of the representation of stories. Trabasso and Sperry, however, did not parse their stories using a story grammar. Their parsing was constrained by a pausal unit analysis based upon procedures of Johnson (1970) that were used by Brown and Smiley (1977) in obtaining the importance judgments. Hence, the relative contribution of categories as well as that of the causal chain under comparable parsing of events cannot be assessed.

In Omanson's study, only the effect of partialling out centrality on the predictive power of the categories was studied, leading to the impression that centrality contributed more *unique* variance. However, the reverse effect of category on centrality was not studied by Omanson. Centrality may covary with the category as well as with the connectivity factor. Statements which are central in a story must contain certain episodic and categorical information (e.g., settings, initiating events, goals, actions, and outcomes). They must be causally determined, and have causal consequences, and are thus likely to have more connections than events not in the sequence. These properties were found for the six stories analysed by Trabasso and Sperry (1985).

In the case of Black and Bower, similar arguments prevail. Step-wise regression does not provide estimates of common and unique variance. The critical path and certain categories are likely to share common properties as well as have more connections. The "hierarchical" status of the statement may depend upon the latter factor. Goals that are superordinate in a sequence of goals, in general, determine more events. However, this is not always the case. Trabasso and Sperry (1985) have shown that subordinate goals may dominate the action in a story, have more direct causal connections, and be judged empirically as more important. Van den Broek and Trabasso (in press) found that superordinate goals were more frequently summarized only when they were in a causal chain and had more connections.

In an investigation comparing all three factors, Trabasso et al. (1984) employed the logical criteria of "necessity in the circumstances" (Mackie, 1980) to identify causal relations between pairs of events for four stories used by Stein and Glenn (1979). Assuming transitivity of causal relations, the pairs were assembled into causal networks. The number of direct connections for events were found from the network. Then the causal chain was found. The chain was opened with setting information and closed with goal attainment or the direct consequences of goal failure. Membership in the causal chain was determined by whether an event's causes and consequences could be traced from the opening to the closing of the chain. The Stein and Glenn (1979) grammar was used to parse the stories.

Trabasso et al. examined how well the three factors predicted the Stein and Glenn (1979) data on immediate and delayed recall. They found that recall across the four stories was linearly related to the proportion of events in the causal chain. Events in the causal chain were recalled more often and showed no retention loss over a 1-week

delay; events not in the causal chain were recalled half as well and showed substantial loss over time. However, the number of direct connections and the category of events both correlated with recall, independent of whether or not the events were in the causal chain.

These data indicate that the causal connectivity and the event category each uniquely accounted for variance in recall. However, since Trabasso et al. did not apply regression or other comparative analyses it is unknown how much unique variance each contributed or whether there was common variance among the three factors.

Given the present state of affairs on the question as to why some story events are more memorable than other events, the present paper has two purposes. The first one is empirical in nature and assesses, in a comparative reanalysis of both the Omanson (1982b) and Stein and Glenn (1979) corpuses, the relative contributions of story-grammar category, causal chain, and causal connectivity factors to recall and other measures of story understanding (summarizing stories and judging importance of individual events).

The second purpose is to provide a theoretical account of the identified variables and their influence on the comprehension of stories. Underlying the empirical analysis is a conceptual framework that assumes that the story representation (and consequently, retrieval and other operations upon it) depends upon the comprehender's use of naive theories of psychological and physical causality to construct a coherent interpretation of the events as they unfold in the story. This implicit framework, realized in the representation of the story events as a causal network, is tested by its ability to predict the data by the causal chain and connectivity factors. The theory, however, assumes processing of content that corresponds to the categories identified in the grammars. Following presentation of the reanalysis of the Omanson and Stein–Glenn corpuses, we shall describe a representational system that incorporates all three factors, and that generates descriptions of both episodic and hierarchical structures.

METHOD

The Omanson Study

Omanson (1982b) had four groups of 18 college students perform one of four tasks. Each student read, at a self-paced rate, three different stories. After reading each story, the student either (1) immediately recalled the story, (2) returned 1 week later and recalled the story, (3) rated each statement in the story as to its importance on a 7-point scale, or (4) summarized the story. Omanson parsed the stories according to the rules of the Stein and Glenn (1979) grammar.

Omanson varied the centrality of selected statements while keeping their content constant across story versions. The categories for which content was controlled were internal responses (goals, cognitions, or emotions) or reactions (actions, emotions, or cognitions). In order to better understand Omanson's control of content, the three versions of the *Turtle* story are presented in Table 1.

Note in Table 1, that the three versions contain common statements. Statements 8, 9, and 10 form a set of internal responses and statements 13, 14, and 15 form a set of reactions, both of which are common to the three story versions. In Version 1 (statement 10) "Mark had always wanted Sally to see a turtle" has causal antecedents (statement 5) and consequences (statements 11 and 12) which eventually result in two major outcomes (statements 19 and 20), making it "central." However, in Versions 2 and 3, this statement (9 in each version) is caused but has no consequences and, hence, is noncentral. An identical analysis holds for statement 15 in Version 1. Examination of statements 8, 9, 13 and 14 for Version 1 shows that these statements are noncentral but that either 8 and

TABLE 1
VERSIONS OF THE TURTLE STORY[a]

Statement (category)	Version 1	Version 2	Version 3
1(S)[b]	*One day Mark and[c] Sally were sailing their toy sailboat in the pond.*	same	same
2(IE)	*Suddenly, the sailboat began to sink.*	same	same
3(IR)	**Mark was surprised.**	same	same
4(A)	*He lifted the boat up with a stick.*	*He waded out to the boat*	*He pushed the boat onto shore with a stick*
5(C)	*and found a turtle on top of it.*	same	same
6(R)	**The turtle became frightened**	same	same
7(IE)	**and tried to crawl off the boat.**	same	same
8(IR)	**The turtle put Mark in a playful mood.**	same	**Mark thought the turtle was hurt.**
9(IR)	**Mark thought the turtle was hurt.**	**Mark had always wanted Sally to see a turtle.**	same
10(IR)	*Mark had always wanted Sally to see a turtle.*	*Mark thought the turtle was hurt.*	*The turtle put Mark in a playful mood.*
11(A)	*so he waded out to the turtle*	*He gently tried to lift the turtle off the boat.*	*He tried to tie the boat to the turtle's back.*
12(C)	*and brought it back to her.*	*but found that its foot had poked through the sail.*	*but the turtle bit him on the hand.*
13(R)	**Sally thought Mark was going to hurt the turtle.**	**Sally felt sorry for Mark.**	**Sally thought Mark was going to hurt the turtle.**
14(R)	**Sally felt sorry for Mark.**	**Sally tried to touch the turtle.**	same
15(R)	*Sally tried to touch the turtle*	*Sally thought Mark was going to hurt the turtle.*	*Sally felt sorry for Mark.*
16(IE)	*but the turtle bit her.*	*So when Mark got out his pocketknife,*	*When Mark saw how Sally felt,*
17(IR)	*Sally didn't like this*	*Sally got upset.*	*It made him very proud.*
18(A)	*and threw the turtle into the pond.*	*She tried to grab the turtle away from Mark.*	*Mark tried to show Sally his wound*

TABLE 1—*Continued*

Statement (category)	Version 1	Version 2	Version 3
19(C)	*The turtle crashed into the sailboat.*	*and accidentally broke the boat's mast off.*	*and accidentally stepped on the sailboat.*
20(R)	*Sally knew she had made a mistake.*	*Sally knew she had made a mistake.*	*Mark wished he hadn't tried to act so big.*

[a] Reprinted, by permission of the publisher, from Omanson (1982b).

[b] The notation for the Stein and Glenn (1979) story grammar categories is: S = setting, IE = initiating event, IR = internal response, A = attempt, C = consequence, R = reaction. Although not shown here, internal responses may be subdivided into goals, cognitions, and emotions while reactions may be subdivided into cognitions, emotions, and actions.

[c] The italicized statements are those in the causal chain; the boldface statements are dead-end events.

13 become central in Version 2, whereas 9 and 14 become central in Version 3. Thus, identical content was central or noncentral across the three versions of a story. Omanson's two other story versions (*Bee* and *Airplane*) are available upon request from the first author.

Causal Network Analysis

Trabasso and Sperry (1985) have described in detail the criteria and procedures for identifying causal relations in stories using Mackie's (1980) logical criterion of necessity in the circumstances. The same criterion and procedures are used here. In order to save space, we shall not repeat the analysis in detail. Essentially, the analysis assumes that the comprehender infers a context in which events of the story occur. This context is called a set of circumstances which undergoes revision as new information accrues in the story. The circumstances create a larger set of causes and conditions which allows single events to be only necessary or necessary and sufficient. In identifying a causal relation between event A and event B as necessary in the circumstances, a counterfactual criterion is applied: Event A is said to be necessary for event B, in the circumstances, in that if event A had not occurred, then event B also would not have occurred. A causal relation, by these criteria, defines a logical dependency between A and B. An event is sufficient, in the sense that if event A is put into the circumstances and the events are allowed to go on from there, event B will occur.

Using the procedures of Trabasso and Sperry (1985) and Trabasso et al. (1984), causal relations between pairs of events in all nine story versions of Omanson's (1982b) study were found. For the nine story versions, there were a total of 2088 possible connections. Of these, 234 direct, operative causal connections were identified. The authors independently judged the relations. The κ statistic on the agreements was .96 ($p < .01$); the proportion of causal relations agreed upon was .88. All disagreements were resolved by discussion and reapplication of the counterfactual tests.

Figure 1 shows the causal network for the three versions of the *Turtle* story of Table 1. The causal networks for the three versions of each of the other two stories are available upon request from the first author.

Causal-Chain Identification

Following Trabasso et al. (1984) and Trabasso and Sperry (1985), the causal chain is opened with those events that introduce the protagonist(s), set the time and locale, and initiate the story's action. The closing of a story is defined in terms of what hap-

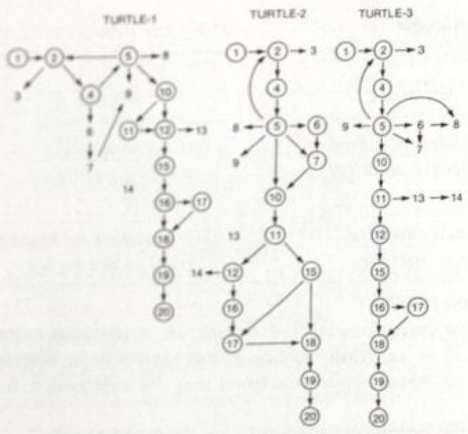


FIG. 1. Causal networks for the three versions of the *Turtle* story. Circled events are on the causal chain; uncircled events are dead-end. The direction of the relation (→) is from cause to consequence.

pens to the protagonist's goal(s). If the goal is attained, the causal chain ends with statements that indicate goal attainment; if the attempts fail, the causal chain ends with the direct consequences of the failure. Once the opening and closing statements are identified, one traces the events via causal connections from the opening to the closing events. Those events that have causes and consequences leading from the opening to the closing are in the causal chain. Those events that lack causes or that do not eventually lead to the closing events are "dead-end" (following Schank, 1975). In general, the causal chain consists of the longest chain of events through the story. In Figure 1, causal-chain events are circled numbers while the dead-end events are left uncircled.

The two authors independently judged which events were in the causal chain and agreed on 95% of the events. Disagreements were frequently on where to end the chain, with either outcomes or emotional reactions. These differences were resolved by discussion, using the rule that if the reaction was to a failed attempt, it should be included in the chain. For the 198 statements classified as belonging to the causal chain, the κ statistic was .76 ($p < .01$).

The causal-chain identification was compared with the central-peripheral classification of Omanson. For the statements which varied in content across story versions, there was 87% agreement. For the 27 statements in which content was controlled but varied in centrality across versions, the agreement was 100%. Omanson's intuitive judgments therefore corresponded closely to ours that were subjected repeatedly to the logical test of necessity in the circumstances.

Number of Causal Connections

The number of direct causal connections was found by counting the number of relations (arrows or intersects) for a given node in the causal network.

Story-Grammar Categories

Omanson (1982b) used the Stein and Glenn (1979) grammar to parse his stories. We parsed the stories using the same grammar and agreed on 96% of Omanson's classifications. We therefore adopted Omanson's parsing for purposes of comparison.

Stein and Glenn Study

Stein and Glenn (1979) had fifth grade children listen to and then recall each of two stories. The children were asked to recall each story again 1 week later. Stein and Glenn used a total of four different stories. Trabasso et al. (1984) derived causal networks for each of the four stories. Their causal chain and the connectivity properties of these networks are used in the present analysis. The data for prediction are the number of children recalling each statement in each of the four stories.

RESULTS

Effects of Category, Causal Chain, and Causal Connections

The first set of results reports the main effects of causal chain membership,

number of direct connections, and categories on each of the four dependent measures for the Omanson (1982b) study. These main effect findings are compared with those found for the same factors by Trabasso et al. (1984) on the Stein and Glenn (1979) data. Following the presentation of these descriptive statistics, the multiple regression analyses on these factors are reported.

Causal-chain effects. Table 2 summarizes the main effect of a statement being in the causal chain or not. Note that a low, numerical rank means that a statement was high in importance. These effects are shown separately for statements that were controlled or that varied in content across story versions.

In Table 2, events in the causal chain regardless of whether the content varied or was controlled over versions were recalled more often than dead-end events in both immediate and delayed recall. Comparing the two recalls shows less of a loss over time for causal chain events. These data replicate the findings of Trabasso et al. (1984) on the Stein–Glenn recall. Causal-chain events also had higher probabilities of being summarized, and they were rated as more important.

Connectivity effects. The effect of the number of direct connections is shown in Table 3. The effects are given separately for causal chain and for dead-end events.

The proportion of events recalled or summarized increased with the number of connections. The exceptions are those events with one connection which tend to be recalled or summarized with higher probabilities than those with two or even three connections. Inspection of the statements that had one connection revealed that these were largely setting statements which begin the story. However, when one examines the importance ratings, these statements fade into the background, so to speak, and there is a monotonic relationship between the number of connections and importance ratings for both causal-chain and dead-end events. The recall data in Table 3 replicate the finding of Trabasso et al. (1984) on the Stein and Glenn (1979) data.

Category effects. Six categories were used in the analysis: settings, initiating events, internal responses, attempts, consequences, and reactions. For each story, the rank order of the categories was found for each measure, separating those categories in the causal chain from those which were dead-end. The average rank-order correlation for the 36 (4 measures × 9 stories) ranked sets was $r = .69$ for causal-chain events and $r = .59$ for dead-end events, respectively. The average ranks are shown for each category in Table 4.

The ranking of the categories was largely independent of the events being on the causal chain, and the order of the catego-

TABLE 2

CAUSAL-CHAIN VERSUS DEAD-END EFFECTS: MEAN PROPORTIONS RECALLED OR SUMMARIZED AND AVERAGE RATINGS OF IMPORTANCE[a]

Measure	Causal chain	Dead end
A. Statement content varied		
Immediate recall	.63	.36
Delayed recall	.39 } .38	.15 } .58 loss rate
Summary	.69	.35
Importance rating	2.48	4.38
B. Statement content controlled		
Immediate recall	.50	.38
Delayed recall	.27 } .46	.12 } .68 loss rate
Summary	.54	.38
Importance rating	3.33	4.55

[a] Data from Omanson (1982b).

TABLE 3
EFFECT OF CONNECTIONS[a]

Measure	Number of connections				
	1	2	3	4	5–7
A. Causal-chain events					
Immediate recall	.62	.58	.61	.70	.92
Delayed recall	.49	.35	.34	.47	.70
Summary	.78	.62	.66	.77	.97
Importance rating	3.55	2.74	2.57	2.04	1.29
	0	1	2	3–4	
B. Dead-end events					
Immediate recall	.34	.37	.38	.34	
Delayed recall	.15	.22	.14	.27	
Summary	.27	.37	.30	.50	
Importance rating	4.93	4.35	4.31	3.46	

[a] Data from Omanson (1982b).

ries corresponds to that found in studies previously cited. The category findings replicate those of Trabasso et al. (1984) on the Stein and Glenn (1979) corpus. The only exception was for attempts. This category ranked low when it was in the causal chain but ranked high when it was a dead-end event.

Regression Analyses

Full regression analyses on the three factors (number of connections, categories, and causal-chain status) were performed for each of the four measures in the Omanson corpus and for the two measures of recall in the Stein–Glenn corpus. The number of connections of a statement was recorded on an interval scale. Causal-chain membership and grammatical category of a statement were recorded on nominal scales. The data in the left side of Table 5 summarize the results in terms of the proportion of variance accounted for (R^2) by the three factors on each dependent measure in each corpus. Table 5 shows that high, significant proportions of variance were accounted for by the three factors, ranging from 32 to 65%.

Alternative Properties of the Statements

Two candidates known to affect recall of sentences were considered as alternatives: serial position (Klatzky, 1980) and concreteness (Paivio, 1971). To index serial position, statements were ranked by starting with rank value = 1 for the first and last statements of the story. The second and the second-to-last statements were given rank value = 2, and so on, until all statements were ranked. The same analysis was performed on the statements in the Stein and Glenn (1979) stories.

To test concreteness, 12 undergraduate

TABLE 4
EFFECT OF CATEGORY: AVERAGE CATEGORY RANK ACROSS ALL MEASURES[a]

Network status	Category					
	Setting	Initiating event	Internal response	Action	Consequence	Reaction
Causal chain	2.25	2.50	5.00	5.50	1.50	4.25
Dead end	2.50	3.50	5.00	2.25	2.00	5.75

[a] Data from Omanson (1982b).

TABLE 5
PROPORTION OF VARIANCE ACCOUNTED FOR BY TWO MODELS

Measure	3-Factor model	F^a	5-Factor model	F^b
Omanson (1982b) data				
Immediate recall	.32	7.92	.33	7.05
Delayed recall	.44	13.39	.46	11.88
Summary	.43	12.79	.44	11.01
Importance rating	.65	26.81	.66	31.98
Stein and Glenn (1979) data				
Immediate recall	.55	12.16	.61	12.36
Delayed recall	.63	16.81	.66	15.11

[a] df = 11/186 and 9/89 for Omanson and Stein–Glenn, respectively. All $p < .01$.
[b] df = 13/184 and 11/87, respectively. All $p < .01$.

volunteers at The University of Chicago were recruited by a newspaper ad and were paid to rate each statement in each of the nine Omanson and four Stein–Glenn stories on a 5-point rating scale from very concrete to very abstract. They were instructed that concrete events are those that are easy to observe or to imagine. In contrast, abstract events are difficult to observe or to image. Statements were rated one at a time and in succession for a given story. For each story, intercorrelations were found for the 12 judges. For the Omanson stories, the mean inter-rater correlation was .64 with the range from .46 to .76; for the Stein–Glenn stories, the inter-rater correlation averaged .50 (range .40 to .58). All correlations were significant ($p <$ .05). The average rating for the 12 judges for each statement was used in the regression analysis.

Comparing the results of the five versus three factor models in Table 5 shows that the addition of concreteness and serial position factors added little predictive value.

Argument Overlap

In constructing a representation of text, one prominent analysis of coherence relates propositions in terms of the number of arguments that the propositions have in common (Kintsch & van Dijk, 1978). Those propositions that have the greatest number of other propositions related to them are assumed to be highest in the hierarchical structure and, therefore, the most important. Furthermore, the speed with which one can access propositions in memory is related to the number of arguments that the propositions have in common (McKoon, 1977; McKoon & Ratcliff, 1980). This factor, obviously, is free to vary in the stories.

In order to find a distance measure between propositions in terms of the number of common or referring arguments, three analyses were performed. Defining predicates and arguments as verbs, nouns, anaphoric nouns, or pronouns, and adjectives, *bidirectional*, *forward*, and *backward* measures of overlap were calculated. For the bidirectional measure, the number of shared predicates and arguments between two statements, A and B, relative to the total number of arguments in A and in B was found. For the forward measure, the ratio of the total number of shared arguments in statements A and B, relative to the total number of arguments in statement A, was found. For the backward measure, the ratio of the total number of shared arguments in statements A and B, relative to the total number of arguments in statement B, was calculated. For each overlap measure and each story, a statement-by-statement matrix was constructed with these ratios as cell entries. For each of the three matrices, a statement's score was obtained by aver-

aging the cell entries for the row following that statement. Thus, every statement obtained a score for each measure of argument overlap. These measures served as independent variables in the correlation analyses.

The correlations of the three overlap measures with each of the four dependent variables as well as with the number of connections and the causal-chain status for each statement were found for the Omanson (1982b) corpus. The bidirectional and backward argument-overlap measures were not significantly correlated with any of the dependent or predictor variables. The forward measure was correlated significantly but negatively with three of the four dependent measures, a direction in correlation opposite to that expected. The proportions of variance accounted for by forward argument overlap were .03, .07, .03, and .01 in the four respective dependent measures. When argument overlap was entered into a regression following the story grammar categories, causal chain, and number of connections, it accounted for zero unique variance in all four cases. Thus common and referring words in the statements do not account for the variation observed in recall, summarization, or importance ratings.

Unique and Common Variance

In order to obtain a clearer understanding of the relative unique and common proportions of variance accounted for by the three factors of interest, we carried out single and pair-wise analyses of variance or covariance. Covariance was used where connectivity was involved, since this variable was recorded on an interval scale. In the pairwise analyses, the factors were entered in both possible orders in order to assess the reducing effect that one factor would have on the other. In addition, the unique proportion of variance accounted for by each factor after the other two factors were entered was obtained.

In these analyses, there were no significant interactions between any factors. The lack of significant interactions implies additivity of the proportions of variance accounted for by causal chain, causal connectivity, and categories. Figures 2 and 3 display the additive partitioning of the variance in each dependent measure via the use of Venn diagrams for the Omanson corpus and the Stein and Glenn corpus, respectively.

The Venn diagrams in Figure 2 reveal a pattern of interest across the four measures. First, in all four cases, each factor uniquely accounted for significant amounts of variance. Comparing immediate and delayed recall, the amount of variance uniquely accounted for by categories increased substantially from 3 to 17%.

In Figure 2, the causal-chain factor accounted for the most unique variance in the importance ratings and also overlapped extensively with categories and connections, leaving these two factors with 9% of the variance. Summaries, which also involve a judgmental component, showed a similar pattern.

The role of causal connections, per se, seems to be stable across all four measures, contributing from 2 to 4% unique variance and overlapping substantially with the causal-chain factor.

In short, these analyses lead to the identification of common and unique effects of categories and connections. Overall, however, the causal chain accounts for most of the variance in all measures.

The data in Figure 3 support these conclusions with two exceptions since connections accounted for null unique variance, and the amount of unique variance accounted for by categories did not increase in delayed recall as compared to immediate recall. These differences are not readily interpreted. There are a large number of differences between these two studies, including age of the subject and materials.

Relative Comparisons

Recall that Omanson (1982b) reported a

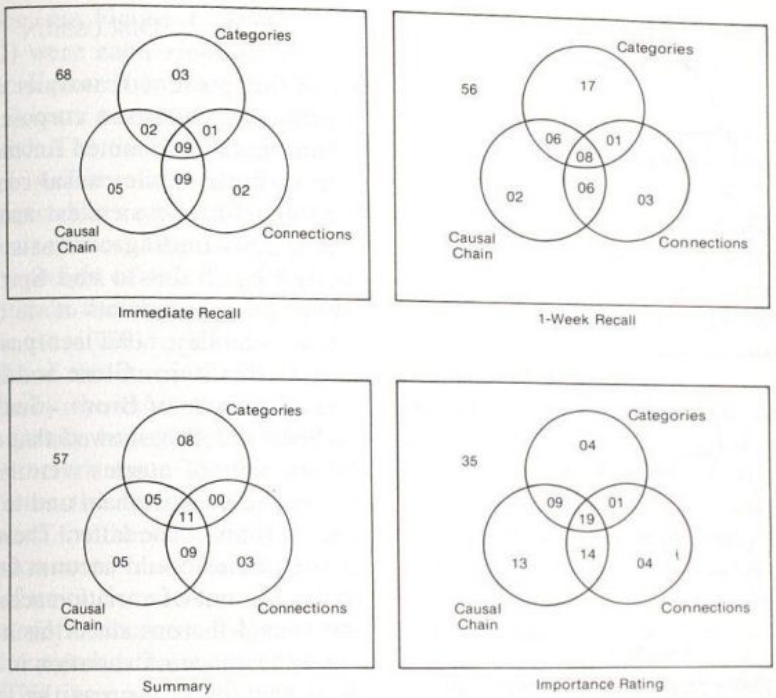


FIG. 2. Venn diagrams of the proportion of variance accounted for by categories, number of causal connections, and causal-chain events for each of the four dependent measures in Omanson (1982b).

75% reduction in the variance accounted for by categories after partialling out the effect of centrality. Figure 2 permits one to estimate any reduction in variance.

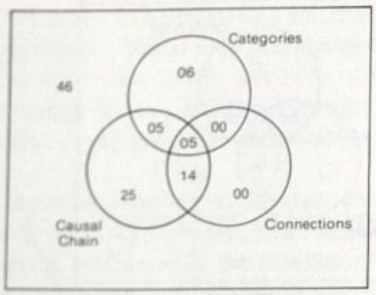
For example, the causal chain reduces the category effect by an average of 67%. In turn, categories reduce the causal-chain effect by 53%. By the same token, connectivity reduces the causal-chain effect by 66%. Pair-wise reduction for all effects averaged 62% (range 50 to 84).

In Figure 3 a very similar pattern is seen for the Stein and Glenn (1979) corpus with an average reduction by 55% (range 27 to 98). These findings indicate that these three factors covary extensively in stories.

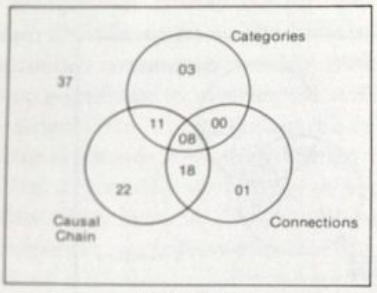
Adjusted Means of Categories

A related question is whether or not taking into account causal network factors materially affected the order in which the categories were recalled, summarized, or judged important. If the finding that settings, initiating events, consequences, attempts, reactions, and internal responses represent an organizational outcome (Mandler, 1984) that is independent of causal factors, then the adjusted means for the categories should retain the same rank order after removing the effects of the causal factors as before their removal. The adjusted means after removal of both the causal chain and the connectivity factors were found via the analysis of covariance for each dependent measure in the Omanson and Stein–Glenn corpuses.

The average rank-order correlations between the ranks of the means before and after removal of the causal network effects were very high in both corpuses. For Omanson, $\rho = .75$; for Stein–Glenn, $\rho = .97$ ($P < .05$). Two changes were noted in each case: attempts moved down five ranks; cognitions/emotions moved up three ranks. The adjusted order was settings, consequences, initiating events, internal responses (goals, cognitions, emotions), reactions, and attempts. These data demon-



Immediate Recall



1-Week Recall

FIG. 3. Venn diagrams of the proportion of variance accounted for by categories, number of causal connections, and causal-chain events for each of the four dependent measures in Stein and Glenn (1979).

strate the independence of the category and causal network effects.

Multivariate Analysis

A multivariate analysis on the four dependent measures, using the three-factor model was carried out. In this analysis, the dependent variables are weighted in an overall score in such a way that the predictive power of each independent variable is maximized, and the proportion of unique variance accounted for by each factor is obtained using Wilks' criterion (Bock, 1975; Wilks, 1932). Estimates of the population parameters (η^2) were .36, .23, and .11 for categories, causal chain, and connections, respectively. Thus, if one were to combine the four dependent measures into a single common measure, the three factors each account for substantial, unique proportions of variance. The categories account for the same amount of unique variance as do the causal network factors combined.

DISCUSSION

In the present reanalysis of the Stein–Glenn and Omanson corpuses, the causal chain factor accounted for the majority of the variance while causal connectivity accounted for the smallest amount of variance. This finding contrasts with that reported by Trabasso and Sperry (1985) on importance judgments of statements in the Brown–Smiley (1977) corpus. A comparison of the Stein–Glenn and Omanson stories with those of Brown–Smiley (Trabasso & Sperry, 1985) showed that events in the former sets of stories were more likely to be on the causal chain and to be less connected than in the latter. These differences in the stories could account for differences in the amount of variation accounted for by the causal factors since this might depend upon the range of variation in the independent variables. Across the three experiments, the percentage of events on the causal chain and the mean number of causal connections were inversely related. The respective proportions of causal chain events for the Brown–Smiley, Omanson, and Stein–Glenn corpuses were .21, .31, and .41; the respective mean numbers of connections were 3.52, 2.62, and 2.25. Statistical tests within each set of means were significant for all pairwise comparisons ($p < .05$). As the proportion of causal-chain events increased, the average proportion of variance uniquely accounted for by the causal chain also increased (.01, .06, and .24), as did the average proportion of common variance (.13, .21, and .23). As the range of connections decreased, so did the average proportion of variance uniquely accounted for by connections (.17, .03, and .005). Thus, systematic variation in properties of the stories correlated with the differences in the amount of variation accounted for in the dependent variables across the three studies.

The inverse relation between the connectivity and causal chain factors reflects differences in story structure. The Brown–

Smiley stories (see Figure 1, Trabasso & Sperry, 1985) were each richly interconnected and nonlinear. The Omanson stories (see Figure 1) were linear and less richly interconnected. The Stein–Glenn stories (see Figures 1–4, Trabasso et al., 1984) had fewer but longer chains of dead-end events than Omanson's stories. The issue, then, as to the relative weight of the causal factors is dependent upon the story structures revealed by the causal network analysis.

The pattern of the amount of variation accounted for by the three factors across tasks within a study, however, does not depend upon structure since the stories are identical. Here, the nature of the processing required for the task plays a role. In the Omanson corpus, we found that the proportion of unique variance accounted for by the categories increased when recall was delayed compared to when recall was immediate. This increase could be attributed to differential loss of information from certain categories or, more likely, the omission of highly inferrable events such as emotional reactions. In immediate recall, more information is available and the content is less dependent upon selection for purposes of communication. With the 10-year-old children in the Stein–Glenn study, however, this result was not replicated. The reason for this difference is unclear.

In the Omanson corpus, the causal role of events increased in weight as the processing requirements shifted from those involving retrieval (recall) to those involving editing (summarizing or judging importance). The respective increases in average proportion of unique variance were from .13 to .17 and to .31. The unique contribution of categories also systematically decreased (from .10 to .08 and to .04, respectively). Hence, decisions about inclusion in summaries and importance appear to reflect criteria involving relational (causal) rather than content (categorical) factors. Decisions about inclusion in retelling the story may depend upon content, at least for mature subjects.

A Recursive Transition Network Representation

In this section, we outline a general recursive-transition network model representation (cf. Frederiksen & Frederiksen, 1982; Polanyi & Scha, 1983) for stories. The network is capable of generating stories that have the kind of variation observed in the Brown–Smiley, Omanson, and Stein–Glenn stories discussed above. It is, however, more general in that it is capable of describing the story structures identified by several, different, theoretical approaches to story understanding. As such, it shows how each approach is a particular realization from a single representation.

The first set of symbols in Figure 4 depicts the general recursive transition network model.

The letters in Figure 4 reflect the names of categories previously described: settings (S), initiating events (E), reactions (R), goals (G), attempts (A), and consequences or outcomes (O). The latter may include actions, reactions, or endings. The subscript (i) refers to the level of embedding of that event in a goal-hierarchy. The subscript (j) indexes the number of the event's category within level (i). Thus, G(11) refers to the first goal at the initial level of the story, G(12) refers to the second goal at the first level and G(21) refers to the first subordinate goal at the second level, and so on.

The relations between events are depicted by arrows. Some relations are required such as those that connect the events in the episode (S, E, G, A, and O); others are optional such as those between emotional reactions and goals, between goals or outcomes across levels or between goals, attempts and outcomes within levels. Some categories may be deleted without loss of information. Goals may be inferred from actions or outcomes; reactions may be inferred from intiating events or goals and outcomes.

The category labels depict the content of events temporally and causally constrained

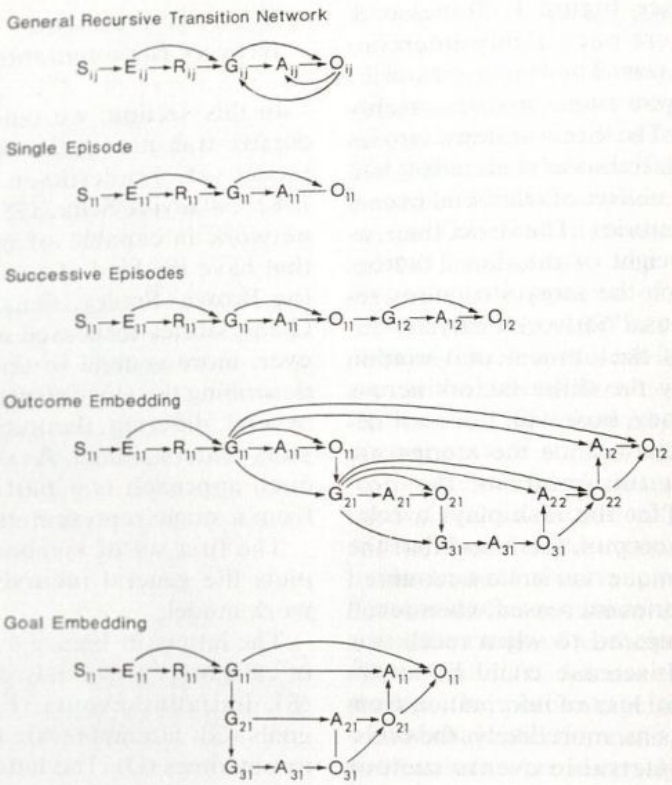


FIG. 4. A general recursive transition network model for stories with generated examples of episodic and hierarchical representations.

by and necessary to an episode. The episodic structure is basic. It reflects a processing outcome constrained by real-world contents and their ordering as well as by the comprehender's application of naive theories of psychological and physical causality to these contents. In order for processing to occur, a context or possible world has to be inferred. There has to be a protagonist in time and space (S), from which the set of circumstances is constructed. There may be several setting conditions joined in temporal coexistence or succession, all of which provide further circumstances. Given the circumstances, one or more initiating events (E) occur which result in internal reactions (R), including emotions and cognitions and goal states (G) for the protagonist. The reactions may or may not bear a causal relation to the goals (e.g., being angry may motivate one to want to harm someone whereas being happy may have no goal consequences). The goal states (G) provide the motivation for what follows, namely, attempts or actions (A) on the part of the protagonist which eventuate in outcomes or consequences (O) of satisfying or not the protagonist's goal. These may be accompanied by further outcomes consisting of reactions, including internal responses such as emotions or actions and endings. This episodic structure corresponds closely to that assumed in the story grammars of Rumelhart (1975), Mandler and Johnson (1979), Thorndyke (1977), and Stein and Glenn (1979) as well as Rumelhart's (1977) try episode and Black and Bower's (1980) transition states.

Within a category, events may cause or be temporally conjoined with events in kind. Thus, initiating events may cause other initiating events, goals may motivate

subordinate goals, actions may enable other actions, and outcomes may cause other outcomes.

The optional relations between events allow the generation of the network and hierarchical structures. Goals not only motivate the initial attempt but all subsequent actions that are directed toward their purposes. When a condition or a cause has effects over time and other intervening events, it is said to be "operative" (Trabasso & Sperry, 1985). This assumption allows distal as well as proximal events to be necessary and sufficient in the circumstances. For example, an action may be enabled by another action but it is motivated or caused by a goal. Outcomes may contain actions that are motivated by goals but lead to goal attainment.

Hierarchical relations depend strongly on the content of the events, particularly outcomes. If an outcome involves goal attainment, a blocked attempt or goal failure, and if the original goal is not abandoned, then another, related goal may be generated and followed by attempts. A subordinate goal depends on the superordinate goal and satisfies criteria of necessity and sufficiency in the circumstances (cf. van den Broek & Trabasso, in press). The subordinate goal motivates new attempts and outcomes. If the second goal is a substitute goal or an unrelated goal, then it occurs at the same level in the network, and generates a successive rather than an embedded episode.

The four lower graphs in Figure 4 depict particular structural realizations of the network. The first, the simple episodic sequence, was described above. Real-world contents and application to them of naive causal theories give rise to the regular, coherent succession of categories in episodic stories. Given the regularity of the content, it is not surprising that the episodic structure is common to all approaches to the representation of stories. Studies that have found effects of systematic category recall (Glenn, 1978; Mandler, Scribner, Cole, & DeForest, 1980; Nezworski et al. 1981) provide indirect evidence for the psychological validity of the episode. More direct evidence for episodic effects per se have been found on recall (Glenn, 1978; Black & Bower, 1979), on processing time (Haberlandt, 1980; Haberlandt, Berian, & Sandson, 1980), and in generation of events from single events (Trabasso, Stein, & Johnson, 1981).

Successive episodes are generated by allowing outcomes to become events that enable or cause new goals. The goals, however, are not dependent upon one another. Rather, successive episodes are caused or enabled by outcomes of the previous episodes. The *Epaminondas* story of Stein and Glenn (1979) is a good example of a narrative with successive episodes where the second episode is caused by the outcome of the first. In the first episode, the boy takes a cake to his grandmother's house. In response, the grandmother asks him to take butter to his mother.

Linear causal chains (Black & Bower, 1980; Omanson, 1982a; Schank, 1975; Warren et al., 1979) may be generated by restricting the connections between events to those that immediately succeed one another. By allowing connections between goals and subordinate goals, goals and more distant actions, and outcomes with outcomes (Trabasso et al., 1984; Trabasso & Sperry, 1985), causal networks (Graesser, 1981) are obtained.

Two forms of embedding are depicted in Figure 4. These correspond to those discussed by Johnson and Mandler (1980), and Mandler (1984). Outcome embedding depends upon success or failure of goals and whether or not these outcome result in new goals. If the outcome was one of goal failure and if this leads to a new subordinate goal, such as Goal (21), then a goal hierarchy results. The subordinate goal is conceptually dependent on the superordinate goal and this relation meets the tests of necessity and sufficiency in the circumstances (van den Broek & Trabasso, 1985). The subordinate goal motivates actions which

may also lead to further failures and generation of other, dependent subordinate goals. In the example, Outcome (31) is successful and enables Action (22) which results in another successful Outcome (22) which finally enables Action (12) which satisfies Goal (11) in Outcome (11). This depiction shows how the network model generates Rumelhart's (1977) goal hierarchy and Stein and Glenn's (1979) outcome embedding. The *Farmer and the Donkey* story of Rumelhart (1975) is an example of a story which is fit by the outcome embedding scheme in Figure 4. In this story, the farmer asks a succession of different animals to help him. Each animal offers help contingent on the farmer meeting one of their goals. When the farmer is finally successful in meeting the needs of the last animal, he is then able to meet the needs of each animal in turn, thereby achieving his original goal.

By allowing the outcomes to fail and not result in a subordinate goal such as Goal (31) or to abandon superordinate goals such as Goal (11), dead-end transitions can be obtained identical to those studied by Black and Bower (1980). By deleting goals, it is possible to generate Lichtenstein and Brewer's (1982) action hierarchies. Lehnert's (1982) plot units and their corresponding affective-state patterns are derivable by taking into account the content of the initiating events, goals and outcomes, and embedded goals.

The second case of goal embedding occurs when the protagonist sets up a goal plan (Johnson & Mandler, 1980; Stein & Glenn, 1979) and generates a number of subordinate goals prior to taking action. *Tiger's Whisker* story of Stein and Glenn is a good example. The lady thinks about how to deceive the tiger into being friendly by playing music which enables her to steal the whisker. Then she does what she thought.

In the goal-embedded example of Figure 4, all the goals succeed. It is possible to have one or more outcome result in goal failure. The *Fox and the Bear* story of Stein and Glenn is a case in point. The fox and the bear plan to steal chickens by going to a nearby farm and breaking into a henhouse. They are successful in reaching the farm and breaking in but fail when the bear falls through the roof, trapping both of them in the henhouse as the farmer comes out.

Figure 4 thus depicts the salient properties and structures of stories that have been focused on by a variety of investigators. It shows how the different structures of interest are special cases that may be generated from a more general system. It also indicates how one might vary the structure in such a way as to have certain properties account for more variance than other properties. One might increase the importance of a subordinate goal, e.g., (21), relative to a superordinate goal, e.g., (11), by adding more actions and outcomes caused by the subordinate goal. Similarly, one might increase the importance of a goal by adding to the story more subordinate goals, while holding constant the number of causal connections each goal has at each level in the hierarchy. Alternatively, one might increase the proportion of dead-end events, making causal chain factors more important, by altering or adding events which, in effect, delete the connections between the outcomes, and goals or subgoals.

The question of what makes an event memorable or important is answered, in part, by knowledge of an event's relations and the structural role that the event has in the representation of the story, relative to those of other events. An event may be remembered, summarized, or judged to be important because of its causal and logical relations, its role in an episodic structure, or its level in a hierarchy or any combination of these factors. In most instances of stories, these properties covary but we have shown them to be independent in their own right.

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