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Causal Reasoning in the Comprehension of Simple Narrative Texts

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This research represents an attempt to unify two separate approaches to the study of text comprehension and recall. The first of these approaches, exemplified by the work of Trabasso and his colleagues (Trabasso & Sperry, 1985, *Journal of Memory and Language*, 24, 595–611; Trabasso & van den Broek, 1985, *Journal of Memory and Language*, 24, 612–630) views comprehension as a problem-solving task in which the reader must discover a series of causal links that connect a text's opening to its final outcome. The second approach, typified by Kintsch and van Dijk (1978, *Psychological Review*, 85, 363–394; van Dijk & Kintsch, 1983, *Strategies in discourse comprehension*, Academic Press, New York) emphasizes the importance of short-term memory as a bottleneck in the comprehension process. We combine these two approaches by assuming that the most likely causal antecedent to the next sentence is always held in short-term memory. This allows a reader to discover the causal structure of a text within the constraints of a limited-capacity short-term memory. We show that three variables derived from this hypothesis (time in short-term memory, causal connections allowed, and referential connections allowed) account for 31% of the variance in the free recall of propositions from eight simple narrative texts.

The research reported here represents an attempt to unify two major approaches to the study of text comprehension and recall. The first of these approaches views comprehension as a problem-solving process in which the reader must discover a sequence of causal links that connect a text's opening to its final outcome (Black & Bower, 1980; Schank, 1975; Trabasso & Sperry, 1985; Trabasso & van den Broek, 1985). The second approach (Fletcher, 1981, 1986; Kintsch & van Dijk, 1978; Miller & Kintsch, 1980; van Dijk & Kintsch, 1983) emphasizes the importance of short-term memory as a bottleneck in the comprehension process. We will show that readers retain in short-term memory the information that is the most likely causal antecedent of the next thing they read. This allows the discovery of a causal sequence linking a text's opening to its final outcome within the constraints imposed by a limited-capacity short-term memory.

Each of the approaches under consideration here has been used to predict how a text will be remembered. In the problem-solving approach, a text's causal structure is seen as the primary determinant of recall. This structure is derived by parsing a text into individual states then using the criterion "necessity in the circumstances" (Mackie, 1980; Trabasso & Sperry, 1985) to determine the causal connections between those states. Thus, *A* is said to cause *B* if it is the case that *B* would not have occurred in the circumstances described by the text had *A* not occurred. By this criterion enablement, motivation, psychological causation, and physical causation are all considered "causal" relations. Recent research

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has shown that two properties of causal networks derived in this fashion influence how a text will be recalled. First, the more causal connections a state has to the rest of the text (either forward or backward), the better it will be recalled (Trabasso, Secco, & van den Broek, 1984; Trabasso & van den Broek, 1985). Second, states that lie along a causal chain connecting a text's opening to its final outcome are recalled (Black & Bower, 1980; Trabasso et al., 1984; Trabasso & van den Broek, 1985) better than states not on such a chain. These results support the conclusion that the causal structure of a text is an important determinant of how it will be understood and remembered.

Kintsch and his colleagues (see, e.g., Kintsch & van Dijk, 1978; Miller & Kintsch, 1980) have developed a more process-oriented approach to understanding text comprehension and recall. They assume that the meaning of a text is represented in memory as a network of propositions called a textbase. Within this representation two propositions are connected only if they are referentially coherent (i.e., they refer to the same person, object, or event) and if they have co-occurred in short-term memory during the comprehension process. Because short-term memory has a limited capacity they suggest that texts are processed in cycles, one sentence or major clause at a time. During each cycle, short-term memory is assumed to hold all the propositions from the current clause or sentence plus a small number of propositions from earlier in the text. Thus, a given proposition might remain in short-term memory for one or many cycles. The longer it stays in short-term memory, the more likely it is to be recalled. More specifically, if p is the probability of recalling a proposition that remains in short-term memory for a single processing cycle, then a proposition that undergoes k processing cycles should be recalled with probability $1\text{-}(1\text{-}p)^k$. A procedure called the "leading-edge strategy" is used to predict the contents of short-term memory during each cycle and, therefore, the value of k for each proposition.

The leading-edge strategy begins with the assumption that the propositions in short-term memory are arranged in a hierarchical network with a topical proposition serving as the superordinate node. All propositions sharing a referent with this superordinate form the second level of the network. Succeeding levels are created by connecting each remaining proposition to the most superordinate proposition with which it shares a referent. Given this hierarchy, the leading-edge strategy works as follows: First, the superordinate proposition is selected for retention in short-term memory. Next, the most recent proposition is selected from each remaining level of the hierarchy. If more propositions are required, the most superordinate remaining propositions are selected in order of recency. If a selected proposition contains another proposition as an argument, the embedded proposition is automatically selected next. The process stops as soon as s propositions have been selected. Under some circumstances, e.g., during the first processing cycle and when the last proposition selected contains an embedded proposition as an argument, $s + 1$ propositions are selected. The value of s is a free parameter of the model. While previous research (see, e.g., Fletcher, 1986; Miller & Kintsch, 1980) has found that the best fitting value of s varies across texts, a value of 2 occurs most often and values in the range of 1 to 4 do not produce statistically different results. Therefore, in applying the leading-edge strategy, we will always assume $s = 2$.

Clearly, there are differences between the two approaches to text comprehension and recall under consideration here. They begin with different units of analysis (clause length states vs propositions). One assumes that two text elements can only be connected if they co-occur in a limited-capacity short-term memory, the other allows all possible connections. Different mechanisms are assumed to contribute to the recallability of a text element (causal structure vs time in short-term memory). Finally, they assume that the components of a text are held together by different relations (causal vs referential). In spite of these very real differences both approaches have generated substantial empirical support, suggesting that each is partially correct. As an initial step toward a unified model, we will test the following hypotheses: (a) That Trabasso's causal analysis can be extended to the level of individual propositions. (b) That the propositions most useful for understanding the causal structure of a text are held in short-term memory during comprehension. (c) That both the amount of time a proposition spends in short-term memory and the number of connections this allows to other propositions influence its recallability. (d) That both referential and causal connections contribute to the coherence of a text.

TABLE 1
THE FARMER AND THE DONKEY

1.	Once there was a farmer
2.	who wanted to get a very stubborn donkey into his barn.
3.	He thought that if he could get his dog to bark,
4.	that would frighten the donkey into the barn.
5.	But the dog was lazy
6.	and refused to bark.
7.	The farmer asked his cat to scratch the dog,
8.	thinking that this would cause him to bark.
9.	Once again his luck was bad,
10.	the cat refused to cooperate.
11.	Next, the farmer thought that if he made the cat angry, she might scratch the dog.
12.	He took a large stone
13.	and dropped it on the cat's tail.
14.	This made the cat angry,
15.	causing her to scratch the dog.
16.	The dog immediately began to bark.
17.	The barking frightened the donkey so badly
18.	that he jumped into the barn
19.	and wouldn't leave for days.

SHORT-TERM MEMORY ALLOCATION

The success of this research depends critically on the assumption that readers can identify and hold in short-term memory the propositions that are the most likely causal antecedents of the next sentence they read. Yet it is obvious that Kintsch and van Dijk's (1978) leading-edge strategy does not accomplish this task. As an example, consider the text in Table 1. It has been parsed into states using two simple rules. First, a sentence boundary always terminates a state. Second, a clause boundary terminates a state only if it separates clauses with different antecedents or consequences. Figure 1 shows the causal relationships among these states (Trabasso & Sperry, 1985). Table 2 shows the propositional structure of the text and identifies the propositions that are essential to the causal role played by each state (i.e., deleting the proposition would cause one or more causal connections to be lost). Finally, Table 3 shows which propositions from earlier in the text the leading-edge strategy would maintain in short-term memory during each processing cycle. Even though Fig. 1 shows a causal link from state 7 to state 10, that link would not be detected by a reader using the leading-edge strategy because, as Tables 2 and 3 show, the propositions that define those states would never co-occur in the reader's short-term memory. This situation is not uncommon; in eight texts that we examined, the leading-edge strategy only allowed 43% of the possible causal connections to be detected. As a result, a reader using this strategy would either miss the remaining connections or have to make frequent, time-consuming searches of long-term memory.

Two alternatives that we have explored offer a significant improvement over the 43% detection rate of the leading-edge strategy. The first of these we call the current-state strategy because the information it selects closely parallels the current state in a state–space search problem. As illustrated by Table 3, a reader following this strategy would select the proposition, or

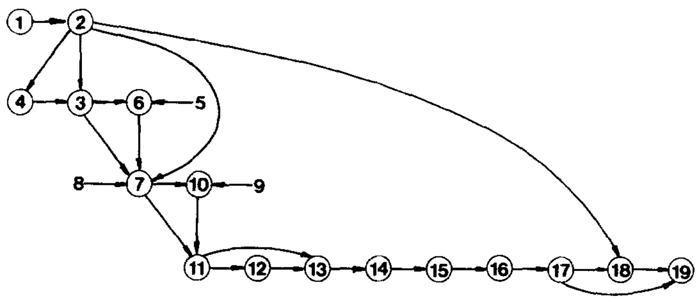

FIG. 1. Causal structure of The Farmer and the Donkey. An arrow from State 1 to State 2 indicates that 2 would not have occurred in the context described by the text had 1 not occurred. States that lie along a causal chain connecting the text's opening to its final outcome are circled.

conjunction of propositions, that comprise the endmost state in the causal chain to retain in short-term memory at the conclusion of each processing cycle. This can be thought of as a two-stage process. First the reader must identify the most recently encountered state which has antecedents in the *preceding* text, but no consequences. Next, he or she must select the propositions from within that state without which it could not serve its causal function (i.e., removal of the proposition would result in the loss of one or more causal connections). This strategy allows 61% of the causal connections in our eight texts to be detected. In addition, the number of propositions retained in short-term memory is allowed to vary and is determined by the causal structure of the text rather than by the parameter *s*.

The other alternative strategy we wish to consider is referred to as the current-state plus goal strategy. A reader using this strategy would always retain in short-term memory the current state in the causal chain (as defined above) as well as the proposition, or conjunction of propositions, describing the most subordinate goal in the text. For the text in Table 1, this would mean additional processing of the propositions that define states 2, 3, 7, and 11. Once again, the strategy is illustrated in Table 3. This strategy represents a significant increase in short-term memory load relative to the current-state strategy, sometimes doubling the number of propositions that must be held-over from earlier in the text. But it allows 70% of the causal connections in a text to be detected and bears a marked similarity to state–space search models of human problem solving (see, e.g., Newell & Simon, 1972). Like the current-state strategy, it also eliminates the need for the *s* parameter in Kintsch and van Dijk's (1978) original model.

We will attempt to determine which of these short-term memory allocation strategies (leading edge, current-state, or current-state plus goal) most accurately describes the performance of college-student readers. Our method, like the model we seek, represents a combination of the two earlier approaches. Each of the short-term memory allocation strategies will be used to predict (a) how long each proposition from eight simple narrative texts remains in short-term memory, (b) how many causally connected propositions, or conjunctions of propositions, it co-occurs with in short-term memory, and (c) how many referentially connected propositions it co-occurs with in short-term memory. These three measures will then be used to predict the free-recall probabilities for each proposition.

To the extent that the current-state or current-state plus goal strategies accurately describe the allocation of short-term memory during comprehension, we can conclude that readers engage in a form of causal reasoning as they read simple narrative texts. These strategies differ, however,

TABLE 2
PROPOSITIONAL REPRESENTATION OF THE FARMER AND THE DONKEY

	Causal State[a]
Sentence 1	
P1 (TIME P2 ONCE)	
P2 (EXIST FARMER)	1
P3 (WANT FARMER P4)	2
P4 (GET-INTO FARMER DONKEY BARN)	2
P5 (MOD DONKEY VERY-STUBBORN)	2
P6 (POSSESS FARMER BARN)	
Sentence 2	
P7 (THINK FARMER P8)	3
P8 (CONDITION P9 P12)	3
P9 (CAUSE FARMER P11)	3
P10 (POSSESS FARMER DOG)	
P11 (BARK DOG)	3
P12 (FRIGHTEN-INTO P11 DONKEY BARN)	4
Sentence 3	
P13 (CAUSE P14 P15)	
P14 (ISA DOG LAZY)	5
P15 (REFUSE DOG BARK)	6
Sentence 4	
P16 (ASK FARMER CAT P18)	7
P17 (POSSESS FARMER CAT)	
P18 (SCRATCH CAT DOG)	7
P19 (THINK FARMER P20)	8
P20 (CAUSE P18 P21)	8
P21 (BARK DOG)	8
Sentence 5	
P22 (TIME P23 ONCE-AGAIN)	
P23 (POSSESS FARMER LUCK)	9
P24 (MOD LUCK BAD)	9
P25 (REFUSE CAT COOPERATE)	10
Sentence 6	
P26 (TIME P27 NEXT)	
P27 (THINK FARMER P28)	11
P28 (CAUSE P29 P31)	11
P29 (MAKE-ANGRY FARMER CAT)	11
P30 (MOD P31 POSSIBLE)	
P31 (SCRATCH CAT DOG)	11
Sentence 7	
P32 (TAKE FARMER STONE)	12
P33 (MOD STONE LARGE)	
P34 (DROP-ON FARMER STONE TAIL)	13
P35 (POSSESS CAT TAIL)	13
Sentence 8	
P36 (MAKE-ANGRY P34 CAT)	14
P37 (CAUSE P36 P38)	
P38 (SCRATCH CAT DOG)	15
Sentence 9	
P39 (TIME P40 IMMEDIATELY)	
P40 (BEGIN DOG P41)	
P41 (BARK DOG)	16
Sentence 10	
P42 (FRIGHTEN P41 DONKEY)	17
P43 (SO-BADLY P42)	17
P44 (CAUSE P43 P46)	
P45 (SET-MEMBERS P46 P49)	
P46 (JUMP-INTO DONKEY BARN)	18
P47 (NEG P48)	19
P48 (LEAVE DONKEY BARN)	19
P49 (DURATION-OF P47 DAYS)	19

[a] State, if any, to which a given proposition is relevant.

in the scope of that causal reasoning. A reader using the current-state plus goal strategy can be viewed as an active problem solver who attempts to relate each new text segment both to its immediate antecedent and to the goal that motivates it. The current-state strategy can be seen as a more passive form of causal reasoning that allows the reader to maximize the local coherence of a text with minimal effort.

METHOD

Subjects

Subjects for this experiment were 48 undergraduate psychology students at the University of Minnesota who received course credit for their participation. All subjects were native speakers of English and participated in groups of eight or less.

Materials

Eight simple narrative texts were used in this research. Some of these were modified versions of texts used in earlier research (the text in Table 1 is an example); others were specifically written for this research. Each consisted of 10 sentences and contained four hierarchically embedded goals. The organization of these goals was systematically varied across texts. Specifically, four separate goal hierarchies were generated (see Fig. 2) and two texts were

TABLE 3
PROPOSITIONS FROM EARLIER CYCLES RETAINED IN SHORT-TERM MEMORY BY EACH OF THREE SELECTION STRATEGIES DURING PROCESSING OF THE FARMER AND THE DONKEY

	Strategy		
	Leading-edge	Current-state	Current-state + goal
Cycle 1	0	0	0
Cycle 2	P3 P4 P6	P3 P4 P5	P3 P4 P5
Cycle 3	P3 P4	P7 P8 P9 P11	P7 P8 P9 P11
Cycle 4	P13 P14 P15	P15	P7 P8 P9 P11 P15
Cycle 5	P13 P14 P15	P16 P18	P16 P18
Cycle 6	P23 P25	P25	P16 P18 P25
Cycle 7	P23 P25	P27 P28 P29 P31	P27 P28 P29 P31
Cycle 8	P23 P25	P34 P35	P27 P28 P29 P31 P34 P35
Cycle 9	P23 P25	P38	P7 P8 P9 P11 P38
Cycle 10	P40 P41	P41	P3 P4 P5 P41

written to conform to each. The purpose of this manipulation is to produce variation in the effort required to hold the most subordinate goal in short-term memory. The more deeply embedded the goal structure, the greater the effort should become. The text in Table 1 is an example of the deep goal structure.

The eight texts were organized into two sets. Each set was composed such that four of the texts were used as fillers and four were used as targets. Texts that were used as fillers in the first set were used as targets in the second set, and vice versa. Each set included one target text corresponding to each of the goal structures in Fig. 2.

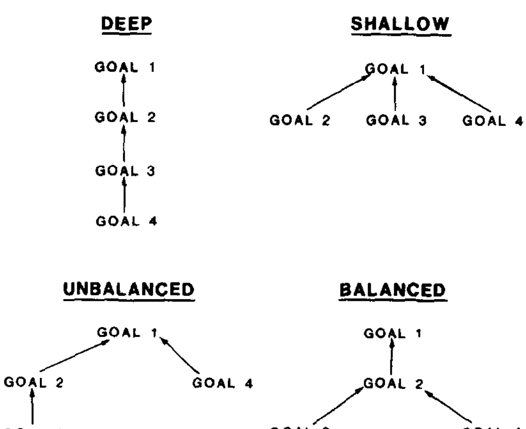

FIG. 2. Four goal structures used to generate the experimental texts. An arrow from Goal 2 to Goal 1 indicates that 2 is a subgoal of 1.

Twenty-four subjects were randomly assigned to each text set. Test booklets were constructed that contained a page of instructions followed by the eight texts in the following sequence: two filler texts at the beginning, four target texts, and two filler texts at the end, followed by free-recall instructions for each of the four target texts. Each subject recalled the target texts in the same order in which they had been presented. Each text and each recall was on a separate page.

Procedure

The experiment consisted of two self-paced phases. During the first phase, all subjects were instructed to read the eight texts once through at their normal reading speed, paying close attention because later they would be asked to recall them. In the second phase, subjects were given the titles from the four middle texts on separate pages and instructed to write down as much as they could remember from each text, using the exact words if possible.

RESULTS

Scoring Recall Protocols

The propositional content of each text (as illustrated in Table 2) was derived using procedures recommended by Bovair and Kieras (1985) and Turner and Greene (1978). The resulting list of propositions was then used to score subjects' free-recall protocols. A strict scoring criteria was adopted such that a subject was credited with recalling a proposition only if it or a close paraphrase of it was explicitly present in the protocol. Two raters scored each protocol. Overall agreement between raters was 96% and all discrepancies were resolved through discussion. After the protocols were scored, the results were used to calculate the probability of recall for each proposition. These are the data to be accounted for by the analyses reported below.

Effects of Causal Structure

The analysis reported in this section is intended to both replicate and extend Trabasso and van den Broek's (1985) findings that the memorability of a text segment is influenced by (a) the number of causal links it has to the rest of the text and (b) whether it lies along a causal chain connecting the text's opening to its final outcome. In the next section we explore the psychological processes that produce these effects.

The causal structure of each text (as illustrated by Fig. 1) was derived using the procedures described in Trabasso and Sperry (1985). This analysis was used to parse the texts into states and to determine the causal chain status and number of causal connections for each of those states. Then multiple regression analyses were carried out on the recall probabilities of each proposition in each story. The independent variables were (a) whether or not a proposition was from a state on the causal chain (Causal Chain Status), (b) the number of direct causal connections a proposition's state had with the other states in the story (Causal Connections Possible), and (c) the number of direct referential connections a proposition had with the other propositions in the story (Referential Connections Possible). Causal Chain Status was a categorical independent variable, with propositions from states on the causal chain receiving a score of one, and propositions not on the causal chain receiving a score of zero. All analyses were conducted on the eight texts combined as well as independently. The pattern of results was the same for all texts (e.g., neither the effect of text nor any of its interactions were significant), so the results will be presented for the texts combined. Because of the theoretical relatedness of the independent variables, a check of multicolinearity was conducted using procedures suggested by Pedhazur (1982). The results of this check indicated no multicolinearity.

As Table 4 shows, Causal Chain Status, Causal Connections Possible, and Referential Connections Possible each accounted for significant proportions of variance when entered into the analysis alone. In addition, both Causal Chain Status and Causal Connections Possible uniquely accounted for significant proportions of variance, while Referential Connections Possible failed to account for any significant unique variance. The interactions of Causal Chain Status with both Referential Connections Possible and Causal Connections Possible were not significant. These results replicate in detail the effects reported by Trabasso and van den Broek (1985). At the same time they extend those findings to a more detailed level of analysis—individual propositions.

TABLE 4
PROPORTIONS OF VARIANCE ACCOUNTED FOR BY CAUSAL CHAIN STATUS, CAUSAL CONNECTIONS POSSIBLE, AND REFERENTIAL CONNECTIONS POSSIBLE

	R^2	
	Alone	Unique
	Full Model = .27**	
Causal Connections Possible	.22***	.02**
Causal Chain Status	.24***	.05**
Referential Connections Possible	.02*	.00

* $p < .05$.
** $p < .01$.
*** $p < .001$.

Effects of Short-Term Memory Allocation

The preceding section confirms that the causal structure of a text influences its comprehension and recall. But the analysis used to demonstrate this influence ignores the limited capacity of a reader's short-term memory. A critical assumption of Kintsch and van Dijk's (1978, van Dijk & Kintsch, 1983) text comprehension model is that two propositions must co-occur in short-term memory to be strongly related in long-term memory. If we accept this assumption, the clear effects of causal structure on free recall force us to examine whether the leading-edge strategy accurately describes the content of a reader's short-term memory during comprehension. These effects only seem possible if the causal structure of a text controls the flow of information through a reader's short-term memory as described by the current-state or current-state plus goal strategies. Therefore, the next set of analyses was conducted to determine which of these strategies is most consistent with our free-recall data.

Each of the short-term memory allocation strategies was fit to the free-recall data in two steps. First, a minimum χ^2 criterion was used to find the value of p which produces the best fit between predicted and observed recall probabilities in the equation Pr(recall) $= 1\text{-}(1\text{-}p)^k$ for each combination of strategy and text. This provides us with a measure of how time in short-term memory alone influences free recall. Next, separate multiple regression analyses on the probability of recall were computed for each strategy, using three independent variables: (a) time in short-term memory (computed as $1\text{-}(1\text{-}p)^k$), (b) the number of direct causal connections a proposition's state had with the other states as allowed by their co-occurrence in short-term memory (Causal Connections Allowed), and (c) the number of direct referential connections a proposition had with other propositions as allowed by their co-occurrence in short-term memory (Referential Connections Allowed). The independent variables associated with each strategy were checked for multicolinearity. None was detected. Sentence boundaries were used to determine the propositions entering short-term memory during each processing cycle. Once again, the effects of text and its interactions with the other variables were nonsignificant, so all results are presented with the texts combined.

Table 5 shows that although all three full models account for significant amounts of variance, the current-state model accounts for the most. Within the current-state model, all three variables alone account for significant proportions of variance. However, only Time in Short-Term Memory and Causal Connections Allowed account for

TABLE 5
PROPORTIONS OF VARIANCE ACCOUNTED FOR BY THE DIFFERENT SHORT-TERM MEMORY ALLOCATION STRATEGIES

	R^2	
	Alone	Unique
Current-state:		
Full model = .31***		
$1\text{-}(1-p)^k$	.24***	.06**
Causal Connections Allowed	.25***	.07**
Referential Connections Allowed	.03*	.00
Current-state plus goal:		
Full model = .27***		
$1\text{-}(1-p)^k$	.20***	.03*
Causal Connections Allowed	.23***	.07**
Referential Connections Allowed	.04*	.01*
Leading-edge:		
Full model = .21***		
$1\text{-}(1-p)^k$	.05**	.01*
Causal Connections Allowed	.19***	.15***
Referential Connections Allowed	.01*	.02*
Random:		
Full model = .18***		
$1\text{-}(1-p)^k$	.00	.00
Causal Connection Allowed	.18***	.18***
Referential Connections Allowed	.00	.00

* $p < .05$.
** $p < .01$.
*** $p < .001$.

significant amounts of unique variance. Thus, within the confines of a limited-capacity short-term memory, assuming a strategy that retains the last propositions added to the causal chain provides the best fit to the data.

One potential problem with these results is that the number of propositions selected by the three strategies varies. Thus, it is possible that the current-state strategy worked best only because it selected an optimal number of propositions. To guard against this possibility a fourth selection strategy was examined. This strategy was matched with the current-state strategy in terms of (a) the number of propositions selected during each cycle and (b) the number of cycles these propositions remained in short-term memory. But the choice of propositions by this strategy was made at random. As shown by Table 5, the only variable that accounts for any variance under these conditions is Causal Connections Allowed. This effect is due to the fact that 28% of the causal connections occur within sentences. When these connections are eliminated, the random model accounts for no variance at all. This allows us to conclude that the current-state strategy accounts for 31% of the variance in our free-recall data *because* it provides a reasonable description of the flow of propositions through a reader's short-term memory during the comprehension process.

Comparison of Structural and Processing Analyses

As a final step in our analysis we conducted a direct comparison of the variables employed in the structural analyses (e.g., Causal Chain Status, Causal Connections Possible, and Referential Connections Possible), with the variables employed in the processing analyses (e.g., Time in Short-Term Memory, Causal Connections Allowed, and Referential Connections Allowed). The results are summarized in Table 6.

TABLE 6
PROPORTIONS OF VARIANCE ACCOUNTED FOR BY BOTH THE STRUCTURAL ANALYSIS AND THE PROCESSING ANALYSIS VARIABLES

	R^2	
	Alone	*Unique*
Structural analysis variables	.27***	.02
Processing analysis variables	.31***	.07*

* $p < .05$.
*** $p < .001$.

This analysis reveals that although both the structural and processing analysis variables alone account for significant amounts of variance, the processing analysis variables from the current-state model account for both more variance and a significant amount of unique variance. Two important conclusions follow from this result. First, a causal connection between the two states does not influence their memorability unless those states co-occur in short-term memory during comprehension. Second, the current-state strategy provides a processing explanation for the effects of causal structure on the free recall of a text.

DISCUSSION

Several important findings emerge from this research. First, we have confirmed Trabasso and van den Broek's (1985) observation that causal chain status and number of causal relations are related to the memorability of a text element. At the same time, we have extended this result to the level of individual propositions. Second, we have presented data which suggest that readers retain the endmost proposition(s) from the causal chain in short-term memory as they read. This is consistent with the general outline of the comprehension model proposed by Kintsch and van Dijk (1978), but clearly at odds with their leading-edge selection strategy (see also, Fletcher, 1986). The status of this strategy for nonnarrative texts remains an open question, however. Third, we have shown that both the number of processing cycles that a proposition remains in short-term memory and the number of connections it forms to other propositions influence its memorability. Fourth, and last, we have found clear evidence that causal connections contribute to the coherence of a text. The importance of referential connections remains less clear.

This research represents a major step toward our goal of integrating two approaches to the study of text comprehension and recall. Our data support the claim that the goal of narrative comprehension is to discover a sequence of causal links that connect a text's opening to its final outcome (Black & Bower, 1980; Schank, 1975; Trabasso & van den Broek, 1985; Trabasso & Sperry, 1985). At the same time, they illustrate the importance of short-term memory as a bottleneck in the comprehension process (Fletcher, 1981, 1986; Kintsch & van Dijk, 1978; Miller & Kintsch, 1980; van Dijk & Kintsch, 1983). It appears that readers use local causal relations to identify the propositions that are the most likely antecedents of the next sentence they read. These propositions are always held in short-term memory and allow us to discover a causal path through a text within the constraints imposed by a limited-capacity short-term memory. It is somewhat surprising that goal information is not held in short-term memory. A likely explanation is that keeping goal information active would create too great a short-term memory load. This suggests that readers focus their attention on maintaining the local coherence of a text. We suspect, however, that goals are reinstated whenever local coherence breaks down (see, e.g., Kintsch & van Dijk, 1978; Miller & Kintsch, 1980). In general, the conditions under which long-term memory is searched for missing antecedents, or consequences, is an important issue for future research.

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