Poetics 9 (1980) 223–250

STORY UNDERSTANDING AS PROBLEM-SOLVING *

JOHN B. BLACK and GORDON H. BOWER

We investigated how people understand and recall simple stories. After discussing our general framework for investigating memory, we examined story grammars considered as theories of readers' memory of a story. Story grammars were found to be inadequate as grammars, as recognition devices for stories, and as predictors of recall probabilities of different statements in three test stories. An alternative approach views a story as a problem-solving protocol and analyzes it into a hierarchical state transition (HST) network; actions were viewed as succeeding or failing to bring about state changes, with actions perhaps being decomposed into subactions. We hypothesized that successful actions, and those higher in the action hierarchy, would be remembered better. Recall evidence supported these hypotheses. First, they predicted recall of statements within our three test stories. Second, people recalled action sequences that were completed, or that succeeded in attaining a goal, better than ones that were begun but abandoned before completion or because they failed. Third, superordinate actions were recalled more than subordinate ones. Fourth, setting information that enabled plot actions was recalled more than unused setting information; moreover, used settings tended to be misrecalled near actions they enabled. Finally we discussed incompletenesses of the HST approach. It requires a processing theory. We suggested some of its components and some story phenomena it must encompass.

Introduction

We are psychologists primarily interested in what people remember from the texts they read or hear. A text is a medium for conveying a social message from a sender to some receivers, and messages can be designed for many different purposes – to entertain, to flatter, to impart knowledge, to provoke an emotional or aesthetic response. Although our reading is often done from habit or for enjoyment, most of it occurs under the explicit goal of remembering the information read. In fact, remembering and utilizing the information in texts and lectures would seem to be the primary focus and justification for formal education. That is one reason for our particular concern with studying how people remember text. The remote hope is that once important causative factors in text-learning are identified, educators will be able to improve the learning process, either by designing more memorable texts or study-aids, or by training more efficient study skills in their students.

* The research of Gordon H. Bower is supported by a research grant, No. MH-13905, from the National Institute of Mental Health of the United States Government.

Experimental analyses of text memory

Psychologists analyze remembering into three components: initial *registration* (*storage* or *encoding*) of the material to be learned, *retention* of the encoded material over an interval, and *retrieval* and *utilization* of it in answering questions or demonstrating a relevant skill. Significantly, these same stages are also identified in analyses of comprehension, although retention receives less emphasis. Remembering depends upon successful completion of all three phases, and experimental variables may influence either stage. Variations in the nature of the text, the readers, or the goals set for the readers primarily affect encoding; variations in the length of the retention interval or in the learning of interfering texts during it primarily affect retention; variations in the conditions of testing (*e.g.*, reproduction *versus* recognition *versus* inferential reasoning) have their effects on the retrieval and utilization phase. In experiments investigating the influence on memory of a particular variable, such as the type of coherence connections among concepts in the text, the experimenter holds constant other variables affecting memory (*e.g.*, the retention interval and type of memory test) while varying his critical variable. Moreover, to generalize the effect of a given variable (like connectivity of text concepts) across different texts, experimenters typically have their subjects read several different texts conforming to a given structure, in each of which the variable of interest can be manipulated.

Text vs. reader variables

Our experiments have been primarily concerned with the structure and content of text and how that affects what becomes encoded into memory. Text memory is a complex phenomenon, and we try to factor it into several parts. A major factoring of variables is into those characterizing the text as a stimulus and those characterizing the reader as a text-consumer and learner. The interpretation encoded into memory depends upon the interaction of these two sets of variables for a given reader and text. Each set of variables can be subdivided further. For example, the text-as-stimulus can be described in terms of the surface realization that is presented to the subject (*e.g.*, whether seen or heard, at a fast or slow rate), in terms of its formal narrative structure, or in terms of its abstract semantic content (*e.g.*, whether causal connections are explicit). Our own work has focussed on variations in semantic content of the passages our subjects read. On the other hand, the variables describing the reader may be divided roughly into those referring to his knowledge about the content or situation described and those referring to his goals, biases or interests in reading the presented passage. Texts which use concepts familiar to the reader and which restate relations familiar to him are easily read because so much of the content is known and predictable; the reader merely has to detect and pause at new information. The reader's knowledge also permits him to draw inferences and connect text elements in a manner that goes beyond the text and which a less knowledgeable reader would be unable to do. Thus, in the absence of knowledge about what typically happens in a restaurant *versus* a meat market, a reader would not have differing expectations from reading "John went into the restaurant and ordered roast beef" *versus* "John went into the meat market and ordered roast beef". A text such as a narrative or a set of instructions is a selective rendering of a continuum of myriad events having differing levels of description. The writer mentions only a few high-points, where critical state-changes occur or where goals are achieved, he leaves out what he considers to be predictable or inessential details, and he writes assuming that his audience will have the necessary knowledge so that they can imagine and fill in the full scenario from the major points and abbreviated description he gives of it. It is on this basis that educators routinely distinguish among texts according to their 'difficulty level', which is indexed roughly by how much specialized or common cultural knowledge the reader must have to understand the text.

The second set of 'person' variables affecting the information encoded from text includes the goals, biases, and interests of the reader. We can pre-set a reader to identify and give especial weight to certain classes of information in a text. This is typically done with instructions or questions given prior to reading, *e.g.*, "Be sure to remember what the text says about the political alignment of European nations at the outset of World War I". This causes the reader to give special attention to and rehearsal of the relevant information so that it is better remembered. But such pre-setting of reading goals can be done indirectly (*e.g.*, by a prior testing history) or by the reader himself. Thus, when each of us reads a complex document (say, the government's proposed budget for the next fiscal year), we will "get out of it" primarily that information most pertinent to our interests and life goals.

The reader's biases and personal style of reasoning also determines how he interprets text and what he remembers from it. Thus, a neutral newspaper account of Moslems rioting in the streets of Tehran will lead to completely different ideological scenarios if the reader is a Marxist revolutionary, a religious libertarian, or a capitalist oil-baron. Each has an ideological script for interpreting the likely causes and sequelae of international events, and it is this interpretation of events rather than the text itself that will be remembered.

Another important class of Person variables for narratives are those affecting which character of a story a reader chooses to identify with. In identifying or empathizing with a given character, the reader adopts the perceptual and emotional perspective of that character, seeing story events through his eyes, reacting to events with his thoughts and feelings. The reader's perspective or point of view influences how he interprets the reasons for events (*e.g.*, 'my' character is competent and has good motives); it influences what objects and properties of the scene appear to be salient (*e.g.*, objects close to 'my' character are more conspicuous); and it influences the station point the reader uses for describing events while remembering (*e.g.*, the storyworld revolves around 'my' character, and events seem to happen in relation to him).

A simple lesson here is that the 'meaning' derived from a text is not a simple mapping of the semantic structures from the text into the reader's memory. This message perhaps needs to be emphasized given the extensive and popular work on text structure and grammars, where the invariable assumption is that the structure of a text is transferred and directs its organization in the reader's memory. But encoding is not a transliteration of text structure into memory. A more accurate perspective is that encoding is an interpretive process in which the reader uses the text as suggestive hints or clues for constructing a mental representation of the meaning of the text for him.

Different text types

There are many different types of text, and it is not feasible to investigate all at once. Literary analysts (*e.g.*, Brooks and Warren 1950) distinguish among forms of prose according to the main purpose of the writer. Their brief list of text types and purposes is:

Description:	to describe what something looked like;
Exposition:	to explain or inform about something;
Argument:	to convince or persuade somebody;
Narration:	to tell what events happened in order.

These are prototypic 'pure forms'; in practice, of course, a writer may use a mixture of literary forms in different parts of the same text. However, texts can be classified according to their predominate form.

We have confined our memory research to that subclass of narratives called 'stories'. A narrative simply relates a temporal sequence of events; a story relates a causal sequence of events relevant to a protagonist pursuing a goal or resolving some problem. Stories have several features that commend their use as research material. First, stories can be easily varied in complexity and difficulty level. Second, prior work on 'story grammars' contains many insights about the structure of stories. Third, dramatic stories are interesting so that readers use their "implicit personality theories" to interpret the actions of the storybook characters, and that allows us to trace the inferences, attributions, and distortions of the text that readers typically display. In this regard, we view story understanding and recall as similar to the processes by which people understand and recall events in their social world. Readers are social-inference machines, and when reading stories they probably use the same inferential routines for interpreting actions, for conjecturing motives, and assigning blame as they do in their social interactions.

For such reasons, our research has focussed on memory for simple stories. In most experiments, we investigated how the semantic structure of an experimental story affected what a reader remembered from it. In other experiments, we varied how the reader was pre-set to interpret a story and we noted how that influenced the way he selected from or distorted the information of the text when later remembering it. To arrive at empirical generalizations, we try to insure the comparability of the experimental stories used as 'replications' or different exemplars of a given plot structure. This is most easily achieved by using short, simple stories (200 to 600 words) we have written especially for our experiments. We realize that such brief stories are *not* 'good literature'; but, then, our goal is scientific generalizations about simple stories, not literary or commercial success.

The structure of stories

Literary analysts agree that simple stories, like folktales, myths, fables, and nursery rhymes, have simple structures. Stories contain constituents such as a setting, theme, plot, episodes, a resolution, all put together in a principled manner to make a coherent unity. Despite these common intuitions, it has proven difficult to discover a proper account of that structure which captures significant generalizations. One approach is to search for the *minimal* essential ingredients that a text must have in order for people to call it a story. Prince (1973) has taken this approach. He proposes that the minimal story consists of five 'syntactic' elements: an initial state description (*e.g.*, "John was sad"); a temporal connective ("then"); an active event ("John met Rita"); a causal connective ("then, as a result"); and a final state ("John was happy"). The final state is frequently the inverse or 'undoing' of the initial state. More complex stories would be constructed by elaborating elements of the minimal story, by adjoining or interleaving many different minimal stories. Prince tries to describe the categories in the minimal story by the order and syntactic nature of the sentences of the text. While we are generally sympathetic to the idea of analyzing stories into states and actions which transform one state to another, a content-free 'base syntax' of stories such as Prince seeks seems an unlikely prospect because stories require rich *semantic* relationships among the states and the actions. For example, the initial and final states must refer to the same agent, the action must be done by or related to him, and the final state must be seen as a plausible consequence of that action operating upon the first state. For instance, an incoherent sequence like "John is sad, then Harry's lawnmower ran smoothly, as a result an earthquake shook Iran" meets Prince's formal criteria for a storyline, yet it fails as a story because essential semantic connections are missing and cannot be filled in.

Story grammars

The most definite proposals about the structure of stories is contained in the 'story grammars', associated with Lakoff (1972), Rumelhart (1975), Thorndyke (1977), Mandler and Johnson (1977), Stein and Glenn (1978), and van Dijk (1977). Story grammars attempt to specify the natural constituents of stories and describe their interrelations. Following the predominate formalism within linguistics, story grammars have been proposed as sets of rewrite rules. Thorndyke's proposed grammar will serve for illustration, since it is one of the simplest.

Thorndyke's first rule is

Story → Setting + Theme + Plot + Resolution.

This rule defines a story as composed of a setting, a theme, a plot, and a resolution. The next rule elaborates the setting,

Setting → Characters + Location + Time.

Thus, a setting consists of characters, location, and time descriptions; a further rule tells us that these are described by states (*e.g.*, "There was a King. He lived in England"). The theme is then defined by

Theme → (Event)* + Goal.

That is, the theme is a goal state of the hero with, optionally, one or more earlier events that set up that goal. The next rule is

Plot → Episode*,

defining a plot as a series of episodes. An episode is defined as

Episode → Subgoal + Attempt* + Outcome;

an attempt is defined as

Attempt → Event* or Episode.

Thus, the plot is a series of episodes, each one of which is a subgoal state, one or more attempts, and an outcome. An attempt is a series of one or more events or an entire episode. Further rules state that outcomes and resolutions can be events or states.

Although Thorndyke's theory is typical, the various story grammars differ somewhat. Two features will be important in our evaluation. One feature is the availability of recursion. In Thorndyke's rules, for example, episodes contain attempts, but then attempts can be rewritten as episodes. This recursive or self-embedding property is present in all of the story grammars except that of Stein and Glenn (1978) which is an incompleteness of their rules. A second important feature of the story grammars is that their rules always change a single symbol on the left side of the arrow into one or more symbols on the right side. Mandler and Johnson (1977) have informally discussed more complex 'transformational' rules that delete symbols (story parts) or reorder groups of symbols, but they have not treated transformations as part of their story grammar. We will discuss transformational rules below.

Evaluation of story grammars on formal properties

Story grammar theories make two general claims: the first claim is that they are grammars for real stories; the second is that they are theories about the representation of stories in memory. We will briefly evaluate story grammars as formal grammars, and then consider their validity as memory theories.

Let us first examine the form of the rewrite rules that define the story grammar. Since the left-hand sides of the rewrite rules contain only single symbols, they must be either finite state grammars (FSGs) or context free phrase structure grammars (CFGs; see Hopcroft and Ullman 1969; Wall 1972; and Bach 1974). The critical difference between such grammars is that CFGs have a self-embedding property whereas FSGs do not. Therefore, the Stein and Glenn theory is FSG, while the rest are CFGs.

Since Chomsky (1957), linguists have demonstrated that both FSGs and CFGs are not adequate as sentence grammars. It would be rather surprsing if they were adequate at the text or story level. Let us see whether the formal arguments against FSGs and CFGs at the sentence level also hold at the story level.

First, we consider whether a FSG is formally powerful enough to represent stories. A FSG cannot handle self-embedding stories. But self-embedding stories, with successive dependent subgoals creating the embedding, are actually quite frequent. For example, the *Old Farmer* story used by Thorndyke (1977), Mandler and Johnson (1977), and Rumelhart (1977) has this form. In this story, an old farmer is trying to get his donkey in the shed (overall goal) by having his dog bark at the donkey (first subgoal, embedded in the overall goal), but the farmer must get the cat to scratch the dog to get the dog to bark (second subgoal, embedded in the first), but to get the cat to scratch the dog he must get the cat some milk (third subgoal, embedded in the second), and so on. This story structure has subgoals embedded in each other; yet it is a perfectly acceptable story. Such stories indicate that a story grammar must be at least a CFG.

But is a CFG formally powerful enough to represent stories? A classic linguistic demonstration of the inadequacy of CFGs involves their inability to represent discontinuous constituents. This situation occurs when a constituent is interrupted by another constituent (that is not a part of the first), but the first continues later. For example, a story might begin with one episode, but then another unrelated episode interrupts it, and the narrative returns to the first after the second ends. Consider the following story fragment:

John was hungry so he hurried down to the local Chinese restaurant. He went inside and was looking for a table, when his friend David came up. David asked if John had seen the latest

Bergman film and John replied . . . Finally they agreed to go to see the latest Herzog film together that Friday, and David left. John found a table and ordered . . .

Here the films episode interrupts the restaurant episode. It contrasts with the *Old Farmer* story where the interrupting and interrupted episode were closely related (*i.e.*, the interrupting subgoal is subordinate to the interrupted goal). A story grammar should treat these two situations differently: that is, the grammar should have one episode interrelation rule that operates when one episode interrupts another and the goals are related, but a different interrelation rule that operates when one episode interrupts another and they are unrelated. In other words, the rules should be sensitive to the context. But if they are, the grammar cannot be context free (a CFG).

Let us next consider whether any phrase structure grammar, even a context sensitive one, is powerful enough to represent stories. The distinguishing characteristic of phrase structure grammars is that the rewrite rules change only one symbol at a time and the length of the left side of a given rewrite rule is always less than the right side. Hence, a rule which deleted a story statement can not be a phrase structure rule. But the need for a deletion rule is apparent from examining even those stories cited as examples parsed by the story grammars. These stories often omit goals and other internal states (motives) and events that are required by the story grammars. If we suppose the 'base story' contains these inferred goals and states, then we could suppose that the surface realization of the story is obtained by a 'deletion transformation' on the base story. If so, then story grammars, like sentence grammars, must be full-scale transformational grammars. In contrast to what seems required, story grammars currently proposed are only FSGs and CFGs, so they are far from formally adequate.

This criticism would not be particularly damaging if one could remedy the situation by merely adding a few transformational rules. In fact, Mandler and Johnson (1977) tentatively proposed deletion and re-ordering transformations for their grammar. However, mathematical results by Peters and Ritchie regarding formal languages indicate that it is the form of the transformational rules that is the crucial part of the grammars (see Bach 1974). In particular, if the transformations are chosen appropriately, then the other rules in the grammar can be of almost any form. If the nature of the transformations is the critical part of a grammar, then the story grammar theorists have not concentrated on an essential aspect of the problem.

Do story grammars accept all, and only, stories?

Besides these formal problems, we will note empirical inadequacies of the story grammars. One empirical test procedure is to invent various texts that intuitively are, or are not, stories and then ask whether the grammars accept them as stories. Ideally, the story grammar rules should generate or recognize all texts that are stories but no texts that are not stories.

A first restriction is that current story grammars do not claim to be completely general; rather it is claimed that they apply only to stories about a single major character striving to reach a single overall goal. Thus, for example, we would not expect them to apply to stories with conflicting goals, or with multiple protagonists.

Even with this restriction, there are still many stories that the story grammars will not generate. However, it is often clear how to add a few more rules to the grammars to cover these stories. The more damaging case against the grammars is that they accept non-stories as stories. One major kind of non-story that the grammars erroneously accept as stories is a procedural exposition. Procedural expositions instruct the reader how to do some task. Graesser (1978) proposed a grammar for procedures that is essentially the same as the story grammars. For example, Thorndyke's story grammar would accept the following procedural exposition as a story:

It is fishing season in Illinois and a friend asks you to go fishing, but you do not know how. Well, I am going to tell you how to catch a fish. First you need to get some fishing equipment. Therefore you should go to a sporting goods store and buy a pole, some line, some hooks, some bait, and a lure. When you have this equipment, you need to find a good place to fish. The best strategy here is to consult either a friend or a guidebook . . . If you follow the guidelines I have set forth here, you cannot help but come home with a batch of fish.

This text contains a setting, theme, plot and resolution as demanded by Thorndyke's or Rummelhart's story grammars. The setting has a time ("the fishing season"), a location ("Illinois"), and characters ("a friend", "you", and "I"). The theme has an initiating event ("a friend asks you to go fishing, but you do not know how") and a goal ("to catch a fish").The plot has several episodes, the first of which has the subgoal of getting some fishing equipment, the attempts (acts) of buying various pieces of equipment, and the outcome of having the equipment. The ending is the resolution, coming "home with a batch of fish". Thus, this non-story text is accepted as a story by our example grammar; with minor modifications it will fit any of the proposed grammars.

So, we have exhibited one class of non-story texts (namely, procedural expositions) that the story grammars accept as stories. We think that this case is not accidental, because we believe that the core intuitions underlying story grammars relate to the planning or problem-solving knowledge that readers use when comprehending both stories and procedural expositions. We believe that stories describe problems and characters' plans for solving their problems. For example, one feature of a proper description of a problem-solving episode is that the final outcome or resolution be told. In this light consider this fragment:

Little Mary heard the ice cream man coming down the street.
She remembered her birthday money and rushed into the house.

Such a fragment is incomplete. As Rumelhart (1977) pointed out, the fragment does not finish describing Mary's trying of a standard plan for obtaining ice cream. This and other examples suggest that perhaps we should characterize well-formed stories in terms of the characters' plans for attaining goals rather than in terms of grammars.

The foregoing argues that story grammars have major failings from both formal and empirical perspectives. We believe that efforts to characterize stories by a grammar are misguided. Intuitive distinctions between stories and non-stories are too vague to formalize into rules. They are much less exact than are intuitions about the grammaticality of sentences. The valuable contribution of story grammars is a beginning characterization of how people utilize problem-solving or planning knowledge when reading stories. This aspect has been the focus of our own research, to be discussed later. First, however, we will evaluate story grammars as theories of memory for stories.

Story grammars as memory theories

To test the story grammars as memory theories, we need rules that use the story-grammar structures to predict what people will remember after reading a story. Rumelhart (1975, 1977) and Thorndyke (1977) tried to predict recall of a fact from its level in the story grammar hierarchy, while Mandler and Johnson (1977) and Stein and Glenn (1978) correlated recall with the type of story constituent to which the fact belonged. The level of a given fact in the hierarchy used by Rumelhart and Thorndyke is the number of rewrite rules of the grammar that must be executed before arriving at the terminal node fitted by that fact. Thus, in the example grammar above, a story statement describing the overall goal would be at level two because two rewrite rules are needed to generate it (*i.e.*, a story has a theme, and a theme is a goal). An attempt-event statement, on the other hand, would be at least level four (*i.e.*, a story has a plot, a plot has episodes, an episode has attempts, and an attempt has events). Applying the rules to a story, a tree structure results, describing the "derivational path" of a given terminal element. Some stories can have many levels (*e.g.*, the *Old Farmer* story has many levels of subgoals). The hierarchy memory rule hypothesizes that the higher the level assigned to a story statement (i.e., the shorter its derivational path), the better that statement will be remembered. For example, this rule predicts that, other things equal, the theme-goal statement of a story would be better remembered than any attempt-event statement.

Different story grammars assign story statements to different levels in their hierarchies. Independent of this level, a story sentence also exemplifies some kind of constituent node as characterized by any particular grammar. For our example grammar above, the node types are settings, goals (including subgoals), attempts, and outcomes (including the resolution). The node-type memory hypothesis states that some of these types will almost always be remembered better than others. For example, Mandler and Johnson (1977) suggest that settings and outcomes will be remembered better than attempts or goals.

We conducted a simple experiment to test the predictions of these two memory rules when applied to the story structures generated by four of the grammars. We used three stories selected from those often used to illustrate the story grammars. Specifically, we used the *Boy* story used by Mandler and Johnson (1977) and Stein and Glenn (1978), the *Dog* story used by Mandler and Johnson (1977), and Rumelhart (1977) and the *Farmer* story used by Thorndyke (1977), Rumelhart (1975), and Mandler and Johnson. Each of these stories was read by a different group of 15 university students, who then performed another task for 20 minutes after which they were asked to write down what they could remember of the story they had read. Their recalls were scored for the gist of the original statements. This scoring yields the percentage of the people who remembered the gist of each story statement. We ranked the story statements from best to worst remembered and used the rankings for the statistical tests below.

We analyzed all three stories into a hierarchy that differed according to the four story grammars (see Black 1977). Using the hierarchy memory rule, we assigned a rank in the hierarchy to the statements in each of the stories. That is, the rankings were determined theoretically by the levels of the statements in the hierarchies generated by the different story grammars. The question of interest is whether the hierarchical ranking of statements assigned by the story grammars correspond to the observed rankings of the likelihood of recall of the story statements in our experiment.

To measure this correspondence of rankings, we calculated correlation coefficients. The results are easily summarized: we obtained not a single correlation coefficient that was significantly different from zero (see Black 1977, for the actual correlation coefficients). Thus the hierarchy memory rule, for either of the hierarchies generated by four story grammars, did not predict the likelihood that the people in our experiment would recall the different statements in the three stories. Therefore, the structural hierarchy assigned to a story by one of these four grammars was not closely related to people's memory of the story's parts.

We next tested the node-type memory hypothesis using these story structures. Testing this hypothesis was more complicated because it suggests no *a priori* ranking of the statement types. To give this rule the best chance to prove itself, we used the average recall percentages of statements of a given type in order to rank the statement types. For example, if the average recall of the other statement types (*e.g.*, settings, attempts, *etc.*) were less than a given type, then we gave its type a ranking of one.

We then calculated correlation coefficients between these theoretical type rankings for each theory and the recall rankings of all the individual statements of each story. A high correlation implies that the different types of statements differ consistently (across instances of a node-type) in their recall. A low correlation means that variability in recall of statements of the same node-type is as great as recall variability between the different types. The actual correlations proved to be quite low: only one correlation coefficient (of 12 = 4 theories by 3 stories) was significantly different from zero (see Black 1977). However, even in this case the correlation accounted for only 14% of the variation in recall of the statements. We conclude that the node-type memory hypothesis does not predict our story memory results.

Causal chain theory

For comparison, we also tested Schank's (1975) theory with our story recall results. Schank proposed a story memory theory that differs considerably from the story grammars. According to Schank's theory, the significant events and states in a story form a causal chain in which each event or state either *results in, enables, initiates,* or is the *reason for* some later event or state in the story. This emphasis on chains of causal events and states suggested different memory hypotheses than those used by the story grammars. We tested the hypothesis that the closer a statement is to the mainline causal chain of the story, the better it will be remembered.

We will use the following excerpt from the *Boy* story to illustrate Schank's causal chain analysis:

(1) One day a little boy's mother told him to take a cake to his grandmother. (2) She warned him to hold it carefully so it wouldn't break into crumbs. (3) The little boy put the cake in a leaf under his arm (4) and carried it to his grandmother's. (5) When he got there the cake had crumbled into tiny pieces.

Statements are numbered for easy reference. The main causal chain here is composed of statements (1), (3), and (5). The mother's telling the boy to take the cake to his grandmother and warning him to hold it carefully together *result in* the boy putting it under his arm (statement (3)), but the first two statements do not have a direct causal link to each other. Putting the cake under his arm *enables* the boy to take it to his grandmother's (statement (4)) but also *results in* the cake crumbling (statement (5)). Thus (4) is a 'deadened' side branch in the chain while the main transition is from (3) to (5). Also (1) to (3) is the first major transition while (2) merely elaborates it. Thus, statements (1), (3), and (5) form the main causal chain, and the memory hypothesis therefore predicts that they should be remembered the best. Statements (2) and (4) are side branches off the main chain, so the hypothesis predicts that they would not be remembered as well.

Correlating the rankings of story statements according to their distance off the main causal chain with their recall rankings, we found highly significant correlation coefficients. Specifically, the correlations of the causal chain rankings with statement recall rankings were 0.52 for the *Dog* story, 0.72 for the *Boy* story, and 0.44 for the *Farmer* story. While far from perfect, the causal theory's predictive power is strikingly superior here to that of the story grammars.

We conclude from these results that Schank's causal chaining theory, not the story grammars, showed the most promise as a theory of story memory. Therefore, we concentrated our efforts on developing that theory. A further analysis indicated a profitable direction for its elaboration.

A hierarchical level variable in recall

The next analysis technique we used was stepwise regression. Given a dependent variable to be predicted and several variables as possible predictors, the stepwise regression method first selects the best predictor, and then selects the next predictor to be most complementary ('orthogonal') to the first. That is, the first step of the procedure selects the predictor variable that accounts for the highest percentage of the predicted variable variation, the second step selects that predictor variable that best accounts for the variation not accounted for by the first, the third step then selects the third predictor variable that best accounts for the variation not captured by the first two, *etc.*

Our variable to be predicted was the recall rankings of the story statements; the possible predictor variables were the rankings determined by the story grammars (using both hierarchy level and statement type memory rules), the Schank causal chain, and two other story memory theories (the hierarchies as assigned to the texts by the theories of Kintsch (1974) and Rumelhart (1977)). We also used the interactions between these variables as possible predictors. If an interaction between two predictors were to be chosen by the stepwise regression, that would mean that the way in which each variable predicts recall is determined by the value of the other variable. For example, if outcome statements were remembered better than attempt statements when they were high in a hierarchy but attempt statements were remembered better than outcome statements when they were low in a hierarchy, then the interaction between hierarchy level and statement type would be a good predictor variable.

We tested the predictive ability of this large group of variables for our recall results using a series of stepwise regressions. We found that the Schank causal chain was still the best overall predictor but it was always improved if it was combined with some 'hierarchy' variable. For example, the best predictor for the *Boy* story was Schank's causal chain index, but a significant improvement could be had by including the interaction between the causal chain and the Kintsch (1974) hierarchy for the story. Using Schank's indices and the first hierarchy variable to appear in the regression, we obtained multiple correlations of 0.88 with recall of the *Dog* story, 0.79 for the *Boy* story, and 0.60 for the *Farmer* story (see Black 1977 for details).

These results reinforced our faith in Schank's causal chain theory and also indicated a fruitful direction for its theoretical development. In particular, the causal chain was always aided in predicting recall by being combined with some hierarchy variable. Hence, the best theory should be one with a hierarchical causal chain. The next section describes the theory we developed.

The hierarchical state transition theory

Black (1977, 1978) proposed a story memory theory called the Hierarchical State Transition (HST) theory. Two lines of reasoning led to this theory. One line was suggested by the pattern of correlation and regression results described above. The other was initiated by Rumelhart's (1977) suggestion that many stories are a 'trace' of a problem solving process. If stories are the traces of the problem solving activities of the characters, then the representation of story structure should be similar to the representation of problem solving. The proposed HST theory uses two common problem solving representations described by Nilsson (1971), *state-transition networks* and *problem-reduction trees*. According to HST, a reader's initial memory representation for a story is the result of his applying these two problem solving methods to understanding the actions of the story characters.

A state-transition network represents a problem solving process as a series of states (really, state descriptions) and actions which change one state into another. The problem solver applies 'means-ends' analysis to the problem (see Newell and Simon 1972), which suggests an action that will reduce the 'distance' between the current state and the goal state. To take a simple example, suppose you are hungry and located in the living room of your home; your goal might be to eat an apple from your refrigerator. In formal terms, the starting state is being hungry and in the living room, and the first action is walking into the kitchen, so that the next (intermediate) state is being in the kitchen though still hungry. The next actions would be opening the refrigerator, getting the apple, and eating it, thus attaining the goal state. A state transition network represents the process of attaining the goal state as an alternating series of state descriptions and transitions between them.

The problem reduction method takes a more hierarchical approach to problem solving. Using this method a problem solver repeatedly analyzes the overall problem into a tree of simpler subproblems until only readily solvable subproblems remain. To illustrate, if we desire a beefsteak, then we need to solve the subproblems of obtaining that food, preparing it to be eaten, and eating it. Next we divide these subproblems into more detailed subproblems. For instance, we can get the steak by going to the meat market and buying it. Thus, the problem reduction method represents the problem solving process as a hierarchy of related actions where the actions lower the hierarchy are more detailed than those higher in the hierarchy.

Problem solving descriptions in stories use both state transitions and problem reductions. We will analyze the following story fragment to illustrate this point:

John was looking for a book for a university class he was taking. First he went to look in the library. He walked up the library steps, went over to the card catalog, . . . Finally he found the book's location in the library shelves. But, unfortunately, the book was not there. So, he went next to look in the bookstore. Just outside the store he looked up the course number in his schedule. He put his briefcase in the rack and . . . Finally, with the clerk's help he found the book.

This story contains state transitions at several levels of detail, the levels related by problem reduction. At the top level, the beginning state of the story is that John does not have the desired book, the transition (major top-level action) is looking for the book, and the ending state is John's having the book. The story decomposes this looking-for-the-book transition into two different subproblems: looking for the book in the library and looking for it in the bookstore. If John could solve either of these subproblems, then he would accomplish the top level transition of obtaining the book. At a further level of detail, the story specifies the library and bookstore searches into their component actions (*e.g.*, "He walked up the library steps", "went over to the card catalog"). Hence this story consists of state transitions at different levels of detail. These levels are related by problem reduction: that is, the state transitions at a given level specify in greater detail how the state transition at the next most general level was accomplished.

Fig. 1 shows how HST analyzes and represents this story fragment. The state descriptions appear in squares, and the state transitions appear as double arrows labeled with ovals. The states and transitions which together comprise a transition network are enclosed in rectangles to indicate their interrelation. The most general transition network appears at the top of the diagram, and the networks become more detailed down the hierarchy. Single arrows link a single state transition at one level with the network which further specifies it at the next level of detail.

A memory hypothesis for the HST theory

To complete HST as a theory of memory for stories, we propose a memory hypothesis that predicts memory accuracy using a structure like the one in fig. 1. We propose the following two part *critical path rule*:

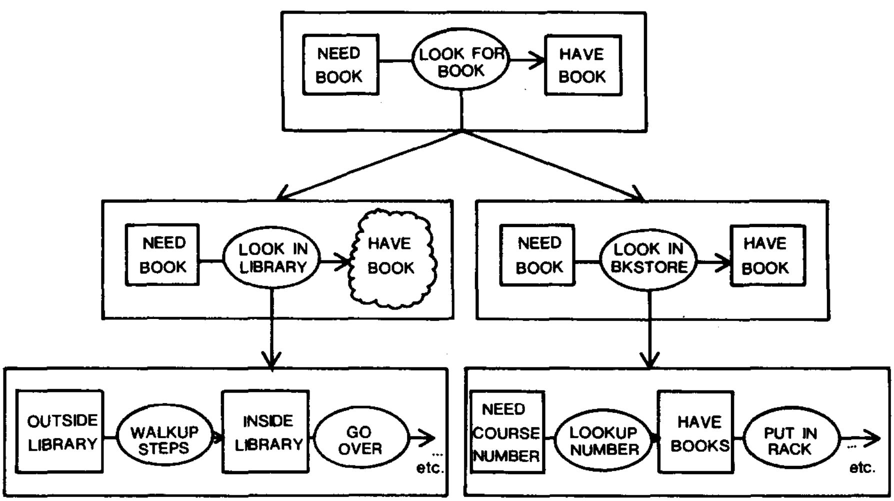

Fig. 1. State Transition theory initial memory structure for example theory.

(1) The best remembered part of a story is the critical path that provides the transition from the beginning state to the ending state of the story.
(2) If the story describes the critical path at various levels of detail, then the higher (*i.e.*, more general, less detailed) the level of a statement, the better remembered it will be.

The first part of this rule is similar to Schank's (1975) causal chain memory rule, which was the best predictor of our experimental results reviewed earlier. The second part of the current rule adds the hierarchical aspect that the stepwise regressions suggested was needed to supplement the causal chain. This critical path rule is consistent with observations by Egan and Greeno (1974) and Reed and Johnson (1977) that what people remembered best about solving a problem was the solution path. The solution path of a (successful) problem solving episode is the sequence of states and state transitions that connect the beginning state to the goal state. The critical path of a story is analogous to the solution path of a problem, so it should be remembered the best.

Black (1978) did two experiments that tested implications of the critical path rule. Applying this rule to the story structure in fig. 1, the following predictions result: (1) the library episode will be less remembered than the bookstore incident because the library episode does not contribute to the state change of obtaining the book; and (2) the "looking in the bookstore" statement is at a more general level on the critical path than the details of what happened in the bookstore, so it will be better remembered than the details. For testing these predictions, college students in one experiment read and later recalled two-episode stories similar to this example. The recall results confirmed both predictions. Specifically, more of the detailed events within an episode were recalled when that episode caused a major state change (48%) than when it did not (40%). Also the more superordinate event statements were better recalled (91%) than the detailed event statements (44%). A second experiment showed that episodes in a story that were interrupted and never completed (*e.g.*, intentions that are only partly carried out) were recalled more poorly (45%) than were episodes that were completed (58%). This result is predicted by the critical path rule because the uncompleted episodes did not cause state changes whereas the completed episodes did.

We also checked the predictions of the HST theory against the results from the recall experiment described in the previous section. We analyzed the *Dog*, *Boy*, and *Farmer* stories into HST structures and used these structures to rank the story statements (see Black 1977 for the structures and rankings). We then correlated these rankings with the recall rankings. We will use the brief *Dog* story to illustrate the HST analysis of these stories.

(1) It happened that a dog had got a piece of meat and (2) was carrying it home in his mouth to eat. (3) Now on his way home he had to cross a plank across a running brook. (4) As he crossed (5) he looked down and (6) saw his shadow reflected in the water beneath. (7) Thinking it was another dog with another piece of meat, (8) he made up his mind to have that also. (9) So he

made a snap at the shadow. (10) But as he opened his mouth the piece of meat fell out, (11) and dropped into the water and (12) was never seen again.

Fig. 2 gives the structure HST tentatively assigns to this story. The main state change is the dog losing his meat. The beginning state, with the dog having the meat, is conveyed in story statement (1), but the top level state transition and the ending state have no corresponding story statements. Statement (2) then begins a chain of events that would result in the dog eating his meat at home, but that state is never achieved so this chain comes to a deadend (the figure shows unattained states in 'clouds'). The story has another level of detail. At this level the dog is initially located at a brook he must cross (statement (3)) and he starts across (statement (4)), but he never makes it to the other side in the story. Hence, statement (4) forms a deadend chain at this level. On his way across the brook he looks down (statement (5)), sees his reflection (statement (6)), and thinks it is another dog with meat (statement (7)), which results in his dropping his meat (statement (10)). Thus, statements (5), (6), (7), and (10) comprise the critical path at this level of detail, which results in the dog losing his meat. There are two further deadend event chains at this level: statements (8) and (9) describe a failed attempt to obtain two pieces

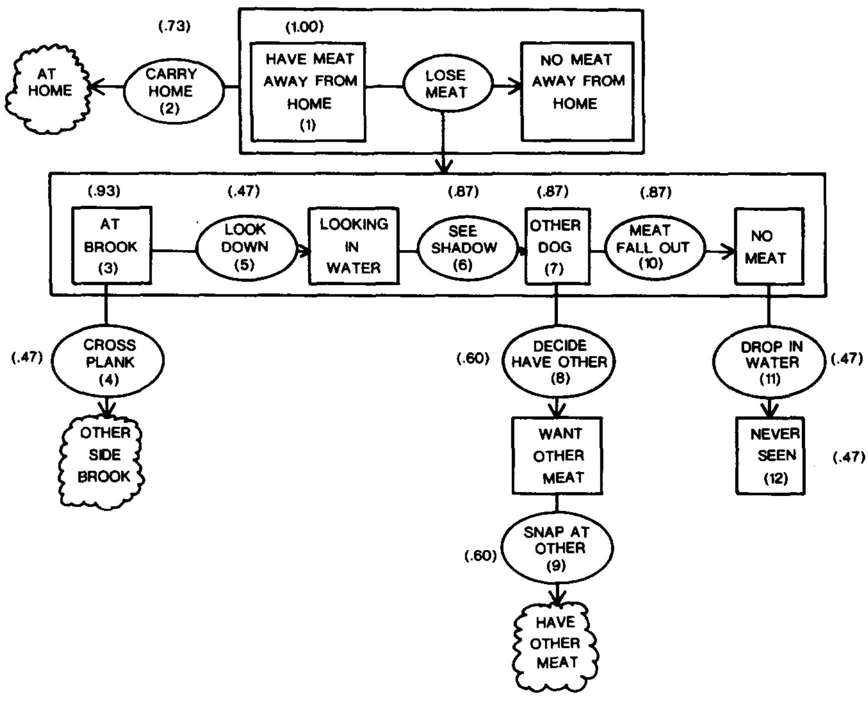

Fig. 2. Hierarchical State Transition theory initial memory structure for Dog Story.

of meat, and statements (11) and (12) tell more about the meat after the main state change of the story has already taken place.

Before proceeding, we should note a certain ambiguity and arbitrariness that arises when analyzing a story by the ideas of the HST. First, state transition networks require triplets of state-to-state transformations via actions, yet real text almost never occurs in this form. Text is abbreviated, elliptical; a state plus a transition may be compressed into a single word, (*e.g.*, "John *killed* Fido"), and many states are merely implied. Consequently, the theorist must often infer the states in the HST analysis. Second, the theorist must decide what goal or subgoal is being pursued at each point and decide whether it succeeds or fails. Failures are actions that do not bring about the desired state change, and they create the 'deadend' chains mentioned above. Interpretive problems arise because failed actions may be embedded within higher-level actions that succeed. Even though an action A may enable some later successful action B, A may not be on the final critical path containing B since A might have been done towards another goal which failed. Thus, in fig. 2, we say that the dog's walking onto the plank (statement (4)) is on a deadend chain since he never gets to the other side, although his being on the plank enables his looking down which results in his losing his meat. Similarly, the dog's snapping at the shadow is said to be part of a deadend chain since its goal (to get more meat) is not attained, although the snapping caused the meat to drop out of the dog's mouth (statement (10)), which is claimed to be part of the critical path. Thus, the HST distinguishes actions according to whether they succeed or fail in bringing about the state change for which they were intended.

After we assigned an HST structure to each story, we then ranked the story statements using a combination of two factors: first, whether a statement was on or off the critical path; and second, the level of detail at which the statement appeared. Statements at the top level of the critical path should be remembered the best, the next level of the critical path the next best, and so on. The statements not on the critical path will be remembered less well than the critical path statements, but we expect off-path statements to be recalled according to that level of the critical path at which they were attached.

Fig. 2 displays the recall probabilities in parentheses for each statement in the *Dog* story. The recall predictions were generally confirmed. Statement (1) is at the top level of the critical path and was recalled by 100% of the subjects. Statements (3), (5), (6), (7), and (10) are on the critical path at the next level and they were all well recalled (93% or 87%), except for statement (5) (47%). The statements off the critical path were all less likely to be recalled and the one attached to the top level (statement (2)) was better recalled (73%) than the ones attached to the next level (47% or 60%). Thus, with the exception of statement (5) which was by chance conjoined syntactically to a poorly-recalled statement, the recall probabilities correspond to our predictions. The HST rankings correlated 0.81 with the recall probability rankings for the *Dog* story. Similarly, the HST rankings correlated 0.91 with recall of the *Boy* story and 0.83 with recall of the *Farmer* story. These correlations exceed the best reported for the other theories in prior sections of this paper. Thus, HST gives a closer account of our experimental results than any other theory that we have examined.

Black and Bower (in press) reported further experimental results consistent with the HST theory. These experiments used two-episode stories similar to the *Book* example given above. Note in fig. 1 that HST separates the 'library' and the 'bookstore' episodes into separate transition networks. Thus, HST implies that story episodes are stored in memory as separate units or chunks. Therefore, events in one episode should have a larger influence upon people's memory for events within that episode than they do upon memory for events in other episodes of the story. In our experiment, we varied the number of events in each of two episodes and found that the number of statements within a given episode affected the probability that people would recall events of that episode, but it had no influence at all upon their ability to recall events from the other episode. That is, the 'list-length effect' on memory was episode specific. The results thus confirmed the HST prediction of a separation of episode events into *chunks* in memory.

While the story grammar theories also predict this separation of episodes into memory chunks, they also imply that the setting information should be chunked separately from the plot. Therefore, we did another experiment like the one just described except we independently varied the length of the setting and the length of the plot. In this experiment, the length of the setting had a significant inverse effect upon the recall of the plot statements, and the length of the plot had a similar effect on the recall of the setting statements. Thus, the results disconfirmed the story grammar prediction that the setting and plot would be stored in separate chunks ('compartments') in memory.

Recall of setting information

Setting statements have a different role in the HST theory than in the story grammars. Specifically, in the HST theory the relevant setting statements are intimately connected to some plot events, whereas the story grammars predict that all setting information will be clustered together in a separate setting constituent. The relevant setting statements in HST either enable (*i.e.*, establish the preconditions for) or serve as the reason for a state transition in the plot. Some setting statements, of course, are irrelevant in not being connected to any essential action of the plot.

The version of the *Book* story used above contained no setting statements. Suppose instead that its beginning contained the following setting statements:

John was a student at Stanford University. Stanford had a large library and a well-stocked bookstore. He was looking for a book that he needed for a course he was taking . . . .

The first statement – "John was a student at Stanford University" – is linked to the 'looking for a book' state transition because it is one reason for that transition.

The next two setting statements are enablements: the existence of the library established by the 'large library' statement enables "looking in the library", and the existence of the bookstore established by the 'well-stocked bookstore' statement enables "looking in the bookstore". Fig. 3 repeats the top two levels of fig. 1 and adds these three background statements. To distinguish the used settings from plot statements, the settings are represented by triangles with dashed arrows linking them to their related state transitions.

This treatment of setting information has two empirical implications which were tested by experiments by Black (1978). First, setting statements are typically connected to the representation of a story only by virtue of their links to the plot events they enable or serve as the reason for. If a setting statement does not link up to some plot event, then it simply will not be connected into that story's representation in memory. The memory theory implies that an unconnected setting would be harder to retrieve from memory than will be one that is connected to the rest of the story. In an experiment to test this prediction, we had university students read stories that contained some setting information which was connected to later plot events via enablement and reason relations, and other setting information that had no such connection to plot events although it was related to the theme of the story. In recalling the stories, the readers recalled 34% of the connected setting statements but only 21% of the unconnected ones. Hence, the experiment confirmed this implication of the HST theory regarding connected setting information.

The HST theory further implies that setting statements are retrieved from memory during recall via their associations to plot events. Hence, we would predict that when people recall a story, they will be biased towards recalling the setting statements together with their related plot events. On the other hand, the story grammar

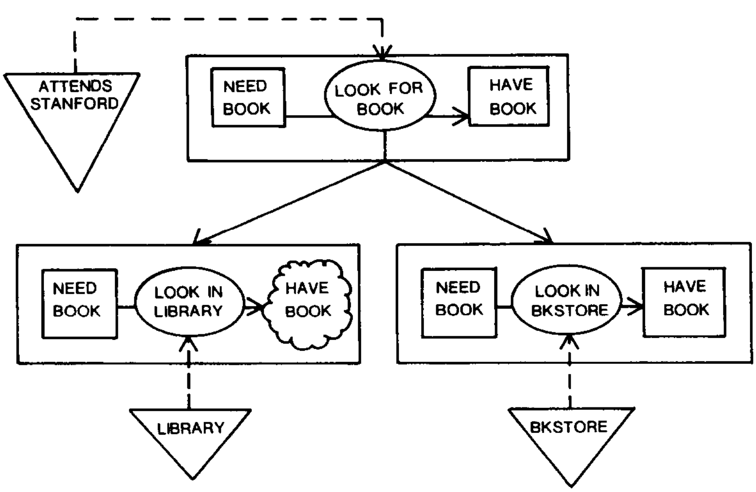

Fig. 3. Representation of background information in the Hierarchical State Transition theory.

theories predict that setting statements should not be recalled among plot events, but rather settings should cluster into a setting constituent at the beginning of recalling the story. In another experiment by Black (1978), students read stories in which half of the setting information was placed at the beginning of the story and the other half was distributed throughout the plot, with each setting statement being placed adjacent to its related plot event. During recall, there was a much stronger tendency for the setting statements presented at the beginning to be recalled at the plot location (42%) than for the setting statements presented in the plot to be recalled at the beginning location (26%). Hence, this experiment confirmed again the HST treatment of setting information while disconfirming the story grammar treatment.

Future development of the HST theory

The Hierarchical State Transition theory is still in a rudimentary stage of development; it is primarily a heuristic for analyzing stories as problem-behavior graphs and as goal-subgoal trees. These heuristics have proved useful for predicting the ordering in recall of elements from different stories. The HST theory predicted recall of the three test stories *Farmer*, *Boy*, and *Dog* better than the other structural theories. Furthermore, our special experiments regarding recall of settings and events on the critical path yielded results as predicted by the HST theory and which appear either unexpected or uninterpretable to most story grammar theories. Having passed these preliminary empirical tests, the HST theory should be regarded as promising and worthy of further elaboration and development. The next sections indicate some developments of the theory which we believe are necessary.

Continued empirical explorations

Three lines of empirical explorations with the HST theory are clearly necessary. First, the theory should be applied to recall results from a greater number and diversity of stories. Recall that our test basis was just three brief stories. So, one urgent need is to examine the theory's recall predictions for many different stories. Second, the basic data for the theory consisted of unprompted *free recall* of complete stories. Clearly, one should examine the theory's predictions for other memory measures such as tests of recognition memory ('True-False' tests), prompted or cued recall, and the time the person takes to remember a given fact. Propositions high on the critical path of the story should be accurately and quickly matched from memory whereas propositions some distance off the critical path should be poorly and slowly recognized. Third, the theory should be extended to predict other aspects of story processing besides memory. Among these would be subjects' judgments of the relative *importance* of different propositions in the text. People can reliably rate how important, salient, or central each proposition is to the content of the story, and these importance ratings correlate with recallability of the propositions. Another measure of story understanding is provided by the summaries or abstracts of a story that readers generate. The hope is that a proposition's height in the HST action hierarchy and its distance from the critical path would predict both its judged importance and its likelihood of being included in a summary.

Development of a process model

The Hierarchical State Transition theory suggests a way to represent in memory the *products* of the process of the typical reader comprehending a story. That representation is in terms of states of the world around the protagonist, and actions which transform those states. Further, the problem of transforming the start state of a story into its end state is represented in terms of a division into subproblems, each of which may be divisible into further subproblems. This analysis will generate an AND/OR graph of subproblems. For example, one procedure that generates subproblems is called 'Precondition Satisfaction': in order to perform some desired action, the protagonist may first have to arrange several preconditions, and so satisfying those preconditions are set as subgoals subordinate to the top action. Because of the duality or translation between intentional actions and goals, the action-methods hierarchy for a story can also be described in terms of its goal-subgoal hierarchy.

Although the HST theory suggests the form of the products of comprehension in the reader's memory, it is seriously deficient in not spelling out the moment-by-moment *process* by which the reader arrives at those representational products. This deficit is the primary focus for the theoretical work in the future. Although we have no process theory at present, we will indicate some of the considerations and issues that must be resolved in arriving at a process model for story comprehension.

Our desired process theory would view a story as though it were the literate, 'thinking aloud' protocol of a verbose character solving an interesting problem; and the reader would be viewed as an interested observer-scientist trying to make sense of the story character's problem-solving protocol. The reader has an implicit theory of planning and problem-solving comparable, say, to the General Problem Solver (GPS) of Newell and Simon (1972), and he is applying his GPS interpreter to the character's protocol line by line to construct a model of that character's problem-solving plan and how his actions relate to it. It is this conjectured *trace* of the character's problem-solving activities (and their associated states) that is alleged to be the story's representation in the reader's memory.

The initial setting of the typical story introduces the hero, sets his goal (or problem), and describes the 'task environment' within which he is to solve the problem. The reader's knowledge surrounding a standard setting tells him something about what actions are possible and which are constrained, (*e.g.*, medieval knights could not communicate by short-wave radios). The reader assumes that the central character will follow a rational plan to reach his goal, that he will use standard techniques of planning, and that he will use standard methods (actions) allowed in that setting as instruments in achieving that goal. All of this attributes much wisdom to readers. But it is entirely plausible to suppose that readers have just such general knowledge about planning, although much of it is tacit and unverbalizable. For example, most readers could be expected to have at least the following knowledge about planning:

(1) goals are derived from basic personal themes such as survival, love, duty, service, greed, avarice, *etc.*;
(2) plans are (real or imagined) series of actions undertaken with the intention of bringing about one or more compatible goals within certain constraints;
(3) actions gain their instrumental value by virtue of their part in a plan;
(4) actions have preconditions and consequences.

Along with such general knowledge about planning, people also have some tacit rules for executing plans. Examples are

(1) if the preconditions of a desired action are lacking, set up a subgoal of establishing those preconditions;
(2) if the preconditions of an action are successfully arranged, do that action; check the consequences of an action to see if they satisfy a goal, or enable other desired actions to be done;
(3) if the preconditions of an action cannot be arranged, then abandon that line of attack and try some other method or action;
(4) if the subgoal-tree for a given plan becomes too deep (too costly or time-consuming), look for an easier solution;
(5) if a problem can be solved by solving any one of several sub-problems (an OR graph), select first the least costly and most likely solvable subproblem to work on. If the problem requires solving several subproblems (an AND graph), if all subproblems are solvable, then work on them in any convenient order; if one subproblem is possibly unsolvable, work on it first; if several subproblems are possibly unsolvable, work on the least costly subproblems first (so if one fails, you have not wasted too much time or effort).

The problem for the reader is not to plan or to execute (or evaluate) a plan but rather to recognize the plan of the protagonist of the story. Plan recognition requires an interplay between 'bottom–up' and 'top–down' processing. The process is top–down when a top goal is stated or implied early in the text, and it suggests standard subgoals and standard classes of actions. For example, if character A (a detective) wants to apprehend character B (the murderer), we know that A will have subgoals such as to get information about where B is, get near to B, and then overpower B. Plan recognition is bottom–up in that the *specific* action taken and its outcome are not predictable in advance; moreover, various obstacles or unexpected deviations can occur at any point in the story, requiring a shifting of schema. Bottom–up processing is required as well for those texts which do not explicitly mention a goal, but which ask that the reader infer the goal from actions or a normative goal-evoking situation. For example, we understand "Rita saw a storm coming, so went into the house" because we know the normative goal in that situation.

If the reader uses his planning knowledge as he reads a story, that will constrain the way he interprets the text and relations among its parts (see Collins *et al.* 1978). As he reads, he is trying to recognize or figure out how text statements relate to the following elements:

(1) Who is the protagonist?
(2) What is his main goal? What subgoals does it generate?
(3) What plan is being executed to achieve that goal? Is it a routine script?
(4) Can this action in the story be identified with some method in the character's plan?
(5) What subgoal was this action intended to achieve?
(6) Did this method just succeed or fail?
(7) If this method succeeds, does its outcome satisfy a precondition of some higher-level action? Which one?
(8) If a method fails, what alternative methods are being called upon to achieve the same higher goal?

These are some of the helpful questions and hints about line-by-line text interpretation suggested by the problem-solving perspective on story comprehension. Schank and Abelson (1977) and Wilensky (1978) have proposed more specific hypotheses about how readers use their planning knowledge in understanding stories. They believe that instrumental goals have standard methods of being achieved in common social situations, and that readers are familiar with these. Some methods enumerated by Schank and Abelson include, for example, getting information, getting close to something or someplace, and getting control over something. Each general method contains more specific ones; for example, getting control over some object can be achieved either by persuading its owner to give it to you, by stealing it, or by overpowering him and taking it. Each general method may have several sub-methods. Persuading someone to give you something has sub-methods such as asking, invoking common interests, bargaining, and threatening (the rule is: if one method fails, escalate to the next higher one or give up). Schank and Abelson believe that large blocks of the same planning methods occur repeatedly throughout simple stories. Thus, as noted above, the standard murder mystery is typically built around the basic sequence of four general methods, namely, the detective must get information about who the murderer is, get information about where he is, get himself to where the murderer is, and get control over him (*e.g.*, arrest him). By repetition across stories, such blocks of methods become familiar patterns. Consequently, the reader can use them to guide his expectations when he reads a new story of a given type. The most extreme examples of repeated, specific plans are *scripts,* which are stylized action routines for stereotyped situations. Situational scripts are so specific that a writer can call forth an entire scenario in the reader's mind by mentioning just a few conventional entries for that script (*e.g.,* eating in a restaurant, attending a cinema).

The point of plans, method-sequences, and scripts is that they provide the reader with a guide for inferring causal linkages between different events in a narrative. Upon inspection, most texts prove to be far too abbreviated and elliptical to be understood by themselves. Rather, the reader must supply many plan-based inferences to fill the gaps the writer left in the interests of literary brevity. We become aware of such gap-filling when we understand a simple vignette like "Junky Jacque desperately needed a fix. He got a gun and went to a liquor store". Readers understand this by inferring the gun will be used to rob the liquor store (a method and subgoal), and the money will be used to buy drugs (the main goal). None of these connections was explicitly mentioned, and a simulation model lacking plan-guided inferential capability would fail to make such necessary connections.

Our basic hypothesis is that the reader uses 'plan detection and identification' for figuring out what is going on in a story. However, we realize that figuring out the protagonist's plan does not provide a complete account of the story. A more complete theory of the reader must add two things: first, a model of the social and physical world in which the protagonist behaves; second, a richer account of the *interaction* of the protagonist's plans with those of his friends or foes in the story.

Storyworld

Readers report that they construct visual images of the scenes being described in stories. They say they use the text to construct and enact a play in the theater of their mind's eye. Perhaps they even sit on top of the shoulders of the characters with whom they identify. We could dismiss such introspections as irrelevant epiphenomena if we could be sure that our theoretically reconstructed hierarchy of propostions and plans characterizing the subject's story knowledge were a complete rendering. However, it is likely that the subject's image of the storyworld has information implicit in it beyond that available in the propositional listing of the scene. The subject can up-date and 'see' dynamic changes of characters, objects, and locations in his storyworld; he has available for inspection not only the starting and ending state of a character's motion but also intermediate points along the dynamic path. The reader can 'see' that objects afford or suggest certain actions and prevent others. Furthermore, the reader's storyworld model allows him to experiment with hypothetical changes in his imagination. So he can imagine *what would have happened* had circumstances been different in the storyworld. Thus, readers can answer questions like, "How would this story have been different if Superman had been unable to fly?", or "If St. George hadn't had a lance, how might he have overpowered the dragon? Could he have pacified and domesticated it?". By such questions, we can learn something about the reader's model of the story world and of the characters in it.

Competing and interactive plans

The foregoing discussion has concentrated on one-character, one-goal stories and focussed on identifying his goal and plan. But interesting stories deal with characters who have multiple conflicting goals. Wilensky (1978) has systematically classified goal conflict situations found in stories; he has also designed a computer program that understands a few such stories and which is able to answer *why*-questions regarding the motivations for a character's actions. Thus, a conflict between two goals of a single character may be of several types:

(1) there may be a limited resource which can be used for one or the other goal, but not both. For example, a character may have only enough money to buy one of two things he wants;
(2) the two goals may involve mutually exclusive states. For example, he can't be in Paris and in San Francisco at the same time; or he can't be legally married to Jill and to Jane at the same time;
(3) pursuit of one goal may endanger loss of an on-going, valued goal. For example, he would like to have the bank's money but robbing it endangers his freedom since he might be caught and jailed.

Goal conflicts between two different characters can be classified into similar categories. For instance, two characters competing to win a race are in a 'mutually exclusive state' conflict; person A's winning implies person B's not winning the race.

Much of what goes on in goal-conflict stories concerns deception and competing anti-plans. In deception, character A tries to conceal his real plan from character B, and perhaps *vice versa.* For concealment, a character may appear to be following a *virtual* plan (a 'front' or apparent 'face') to deceive his adversary, leading him into a vulnerable position (see Bruce and Newman 1978). Thus, a football quarterback will feint a line-plunge in order to draw in the defensive backs as he drops back to pass. The existence of fronts, feints, decoys, con-games, cover-stories, and other social deceptions attests to the fact that people react to the apparent intentions of others, and they construct models of what they think their adversary is thinking of them. The essence of competitive strategy is guessing what your opponent thinks you will do, and then countering his move. A good story informs us of ingenious anti-plans.

Standard moves in anti-planning in competitive conflicts include (see Wilensky 1978):

(1) eliminating your opponent;
(2) sabotaging his actions; for example, undoing a precondition for his effective action or putting obstacles in his way;
(3) foiling those of his actions aimed at disabling you; for example, defending yourself against physical harm;
(4) persuading him to let you win; for example, bargaining for it or threatening him;
(5) easing the conflict; for example, de-escalating the conflict through negotiation, sharing of the prize, *etc.*

By knowing such general strategies about anti-planning, the reader can predict and understand the sort of actions and counteractions he will see in goal-conflict stories. Having classified the type of goal conflict and the anti-planning strategies being used, the reader is in a better position to understand the reasons behind specific counteractions in the story. These motives are part of the "state-descriptions" the HST theory needs to have for the competing protagonists of the story.

Final comment

We have just discussed world-models, goal-conflicts, and anti-planning as components of the process theory needed to supplement the HST theory. Our goal remains as before, *viz.*, to account for the representation of a story in a reader's memory, to describe the real-time process by which that representation was arrived at during reading, and to characterize the knowledge structures used in this process. The theoretical task before us is very large but preliminary work in the area must be regarded as grounds for optimism about progress in elucidating processes of story comprehension and recall.

References

Bach, E. 1974. Syntactic theory. New York: Holt, Rinehart and Winston.
Black, J.B. 1977. Theories of story memory structure. Unpublished manuscript, Stanford University.
Black, J.B. 1978. Story memory structure. Dissertation, Stanford University.
Black, J.B. and G.H. Bower. In press. Episodes as chunks in story memory. To appear in: Journal of Verbal Learning and Verbal Behavior.
Brooks, C. and R.P. Warren. 1950. Fundamentals of good writing: handbook of modern rhetoric. New York: Harcourt and Brace.
Bruce, B. and D. Newman. 1978. 'Interacting plans'. In: R.J. Spiro, B.C. Bruce, and W.F. Brewer, eds., Theoretical issues in reading comprehension. Hillsdale, NJ: Lawrence Erlbaum Associates.
Chomsky, N. 1957. Syntactic structures. The Hague: Mouton.
Collins, A., J.S. Brown and K.M. Larkin. 1978. 'Inference in text understanding'. In: R.J. Spiro, B.C. Bruce and W.F. Brewer, eds., Theoretical issues in reading comprehension. Hillsdale, NJ: Lawrence Erlbaum Associates.

Egan, D.E. and J.G. Greeno. 1974. 'Theory of rule induction: knowledge acquired in concept learning, serial pattern learning, and problem solving'. In: L. Gregg, ed., Knowledge and cognition. Potomac, MD: Lawrence Erlbaum Associates.
Graesser, A.C. 1978. How to catch a fish: the memory and representation of common procedures. Discourse Processes 1: 72–89.
Hopcroft, J.E. and J.D. Ullman. 1969. Formal languages and their relation to automata. Reading, MA: Addison-Wesley.
Kintsch, W. 1974. The representation of meaning in memory. Hillsdale, NJ: Lawrence Erlbaum Associates.
Lakoff, G.P. 1972. Structural complexity in fairy tales. The Study of Man 1: 128–190.
Mandler, J.M. and N.S. Johnson. 1977. Remembrance of things parsed: story structure and recall. Cognitive Psychology 9: 111–191.
Newell, A. and H.A. Simon. 1972. Human problem solving. Englewood Cliffs, NJ: Prentice-Hall.
Nilsson, N.J. 1971. Problem-solving methods in artificial intellingence. San Francisco: McGraw-Hill.
Prince, G. 1973. A grammar of stories. The Hague: Mouton.
Reed, S.K. and J.A. Johnson. 1977. 'Memory for problem solutions'. In: G.H. Bower, ed., The psychology of learning and motivation, Vol. 11. New York: Academic Press.
Rumelhart, D.E. 1975. 'Notes on a schema for stories'. In: D.G. Bobrow and A. Collins, eds., Representation and understanding: studies in cognitive science. New York: Academic Press.
Rumelhart, D.E. 1977. 'Understanding and summarizing brief stories'. In: D. LaBerge and J. Samuels, eds., Basic processes in reading and comprehension. Hillsdale, NJ: Lawrence Erlbaum Associates.
Schank, R.C. 1975. 'The structure of episodes in memory'. In D.G. Bobrow and A. Collins, eds., Representation and understanding: studies in cognitive science. New York: Academic Press.
Schank, R.C. and R.P. Abelson. 1977. Scripts, plans, goals, and understanding. Hillsdale, NJ: Lawrence Erlbaum Associates.
Stein, N.L. and C.G. Glenn. 1978. 'An analysis of story comprehension in elementary school children'. In: R. Freedle, ed., Discourse processing: multidisciplinary perspectives. Norwood, NJ: Ablex Publishing Co.
Thorndyke, P.W. 1977. Cognitive structures in comprehension and memory of narrative discourse. Cognitive Psychology 9: 77–110.
van Dijk, T.A. 1977. Text and context: explorations in the semantics and pragmatics of discourse. London: Longman.
Wall, R. 1972. Introduction to mathematical linguistics. Englewood Cliffs, NJ: Prentice-Hall.
Wilensky, R. 1978. Understanding goal-based stories. Research Report No. 140. Dept. of Computer Science, Yale University, New Haven, CT.

John B. Black is currently an Assistant Professor in the Department of Psychology at the University of Illinois at Chicago-Circle. He received his Ph.D. in 1978 from Stanford University where he worked with Gordon H. Bower, his co-author on this article. His primary research has been on memory for stories and other texts.

Gordon H. Bower is currently Professor and Chairman of the Department of Psychology at Stanford University. He has many publications on learning and memory. He received many honors for his research, including election in 1973 to the American National Academy of Sciences.