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Representing Problem-Solving Episodes

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ABSTRACT

The understanding of simple, narrative episodes in which a protagonist successfully realizes a goal through a sequence of actions is studied. In two experiments, subjects rated the acceptability of sentences of the form "The protagonist does ACT 1 in order that the protagonist could ACT 2", where ACT 2 and ACT 1 were actions from the episode. Ratings were predicted by (i.e., inversely related to) distance within a narrative representation which organizes actions into sequences (action chains) reflecting aspects of the problem-solving plan employed by the protagonist. Subjects separated action chains that had been interleaved in a text. Mishap, irrelevant, and restorative actions were not incorporated directly into an attempt structure. Corrective actions, undoing the ill effects of mishaps, were incorporated. Further research is suggested.

I INTRODUCTION

The episode has been discussed as a major, cognitive constituent of narrative discourse (e.g., Thorndyke, 1977; Rumelhart, 1975, 1977; Mandler and Johnson, 1977). An episode encompasses the situations and actions occurring during a protagonist's efforts to realize a desired goal. The goal may be that of performing a certain action or of establishing a desired situation. Table 1 presents a grammar describing a representation for successful problem-solving episodes. Rule 1 of the grammar indicates that an episode consists of a problem and its solution. Rule 2 indicates that the elements of a problem are a situational context, a triggering event giving rise to a goal, and the goal itself. The triggering event is either an action taken by the protagonist or some external occurrence in the environment (Rule 4).

Rule 6 states that the solution to the problem is represented as one or more attempts to realize the goal. Rule 7 indicates that a problem-solving attempt generates an attempt structure consisting of an action or an action preceded by one or more preactions. The goal action, that directly

subordinate to an attempt, may itself be the goal or may establish the goal situation. A preaction of an action is another action which establishes one or more necessary preconditions of that action. These preconditions are implicit subgoals of the problem-solving activity. Since attention here will be focused on action interrelationships, these subgoal situations are not explicitly represented by the grammar. Finally, Rule 8 states that a preaction is an action or may be recursively expanded into an action preceded by one or more preactions of its own.

The terminal elements of our representation grammar are STATE, ACTION, and OCCURENCE. These elements are to be bound to information elements from a given episode text during understanding either by instantiation of a known, schematic episode representation or by construction of a grammar-based representation. This process corresponds to explaining protagonist's actions (Wilensky, 1978). The attempt structure generated for a given episode represents the (intentional) enablement relations existing among actions of a protagonist's problem-solving activity.

A given action of a text may be bound to several ACTION elements in the attempt structure, establishing necessary preconditions for more than one subsequent action. For example, entering a room may enable acquisition of several instruments necessary to realize the goal of an episode. Furthermore, what appears as one sequence of actions in an episode text may constitute several subsequences of actions, each establishing different necessary preconditions of a single, subsequent action. This is demonstrated in Figure 1, which presents a problem-solving episode and associated representation.

Let an action chain be a sequence of actions which is computed from an attempt structure as follows: Begin with an action bound to an ACTION element subordinate to a PREACTION element having no subordinate PREACTION elements; continue the sequence with actions bound to ACTION elements directly subordinate to successive, parent PREACTION elements; and end with the goal action. For example, the action chains of the episode presented in Figure 1 are (5,6,7,11) and (8,9,10,11). Let the distance $D(a1,a2)$ between actions a1 and a2 of an attempt structure equal the

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(positional) index of a2 actions al and minus the index of al in a common action chain or be undefined if they are not elements of a common chain. For example, D(5,11) is 2 in the episode structure of Figure 1, while D(10,8) equals -2.

When D(al,a2) is positive, the extent to which al enables a2 decreases as D(al,a2) increases. Thus, acceptability ratings of sentences stating such enablement would be predicted to decrease. If the distance measure is less than or equal to zero or if the two actions are not elements of a common action chain, then al does not enable a2. Acceptability ratings should be uniformly low for sentences stating such enablement. We briefly describe two experiments addressing these predictions. A more complete discussion of the experiments and results is presented elsewhere (Farley and McCarty, 1980).

II EXPERIMENTS

Experiment 1 used two different attempt structures to generate four episode texts. The attempt structure for one-chain episodes consisted of a single chain containing seven actions. The attempt structure for two-chain episodes consisted of two action chains each containing four actions; each episode contained seven actions as the goal action was a member of both action chains. A first sentence related the triggering event and goal of the episode; a second provided setting information. The remaining sentences described the sequence of seven actions performed to achieve the goal. One sentence in the active voice was generated for each action. Two surface versions of each two-chain episode were generated. In one, the action chains were interleaved in the text; a sentence describing an action in one action chain was followed by a sentence from the other chain. In the other, the action chains were kept intact; one action chain was completely described before actions from the other were mentioned. Figure 1 is one of the intact, two-chain episodes used. Furthermore, two versions of each intact-chain text were generated, differing in which action chain occurred first.

A set of test sentences was prepared for each episode according to the following general framework: "{Action-1} in order that {pronoun} could {verb-phrase of Action-2}.", where {Action-1} and {Action-2} were bound to sentences describing actions in the episode and the {pronoun} referred to the protagonist. For one-chain episodes, the sentences differed with respect to distance in the attempt structure. All possible positive and zero distance test sentences were generated; sentences with negative distances of -1 and -2 also were generated. For the two-chain episodes, all positive distance sentences were generated such that the main-clause action preceded the purpose-clause action in one version. Sentences differed as to whether or not the two actions occurred within the same action chain.

Subjects received four episodes with test sentences and instructions; they were informed that they were to make acceptability ratings of test sentences. Marking the space next to "NA" indicated complete unacceptability (a rating of 1) while the space next to "A" indicated complete acceptability (a rating of 7). Different degrees of acceptability could be indicated by marking appropriate spaces between the two extremes. Subjects were instructed to read carefully each episode and were allowed to refer to the episode while rating sentences. Results of Experiment 1 are presented in Table 2. In short, results indicated a significant distance effect, with most pairwise comparisons yielding significant differences in predicted directions.

Within a given episode, a protagonist may perform actions which are peripheral to goal satisfaction. Two types of peripheral actions are restorative and irrelevant actions. A restorative action is one that reestablishes a normal situation in the environment disturbed by prior problem-solving. An example would be closing a purse after removing car keys or putting away a tool after using it. An irrelevant action is one that either appears to have no pragmatic utility or to be related to goals external to that of the episode. An example would be smelling a rose while mowing the lawn or turning down the oven while washing dishes. A protagonist may even perform an action that disrupts progress toward the goal of an episode and then must recover from this setback. A mishap is an action that destroys realization of a situation created by prior, goal-directed actions of an episode. Corrective actions are actions that reestablish the situation existing prior to a mishap. An example of a mishap would be dropping a tool, which would elicit the corrective actions of bending down and picking up the tool.

Peripheral actions and mishaps should not be incorporated into the attempt structure for a given episode. As such, acceptability ratings of test sentences involving such actions should be low. On the other hand, corrective actions should be incorporated as elements of a preaction subtree of (or episode subordinate to) the action enabled by the situation they serve to reestablish. As such, corrective actions do enable subsequent actions in an action chain.

Experiment 2 was designed to test the above predictions regarding these four types of actions. Two new episodes contained one restorative and one irrelevant action; a third contained one mishap and two associated corrective actions. Each episode involved only one action chain except for the second action chain produced by the two corrective actions of the third episode. A fourth episode was characterized by actions that were low in a priori associativity, with objects used in novel ways; this episode will not be discussed here. Materials and procedures were as in the first experiment.

The results indicated significant distance effects for all three stories. The Duncan test indicated the following differences among means by distance, $p < .01$: for the restorative/irrelevant stories, $1 > 2 = 3 > 4 > 5$ and $1 > 2 > 3 = 4 > 5$; for the mishap/correction story, $1 \; 2 > 3 > 4$. These results are consistent with those of Experiment 1. Further analyses attempted to answer whether mishaps, restorative, irrelevant, and

corrective actions are incorporated into attempt structures. Two kinds of test sentences were examined for each action type. In one, the critical actions are expressed in the main clause, enabling subsequent goal-directed actions. In the other, the actions of interest occur in the purpose clause, enabled by prior, goal-directed actions. Results indicated that restorative, irrelevant, and mishap actions are not represented as being enabled by goal-directed actions; mean acceptability ratings for such sentences were consistently below 2.0. Ratings were similar for sentences stating enablement by mishap and restorative actions. Some irrelevant actions were understood to weakly enable subsequent goal-directed actions; however, mean ratings were still below 3.0. An in-depth discussion of these results, as well as those for the low-associativity episode, are presented elsewhere (Farley and McCarty, 1980).

Results indicated that subjects understand corrective actions to be part of the goal-directed behavior of the protagonist. However, the enablement relation between corrective and subsequent goal-directed actions was not as strong as the relation between the original goal-directed actions and the same, subsequent goal-directed actions. This effect may well have been produced by differing levels of a priori relational density (Graesser, 1978). In our episode, walking to a bookcase normally is more highly associated with dictionary use than is bending down (to pick up the dropped dictionary). Relational density could also account for an effect of episode in Experiment 1.

III   CONCLUSION

Results of both experiments were generally consistent with predictions made in accordance with the attempt structures described by the episode grammar. The strength of enablement was inversely related to positive distances within action chains and not correlated with surface (text) distances. The action chains computed from the grammatical representations closely resemble causal event chains described by Schank and Abelson (1977). Results obtained here lend support to Schank and Abelson-like proposals, as do recent results of Graesser (1981). We demonstrate the effectiveness of an acceptability rating paradigm for assessing such structures. Our results indicate that only goal-directed actions are incorporated into attempt structures. To state that restorative, irrelevant, and mishap actions are not incorporated is not to say that they are not remembered. It merely says that such actions are not incorporated into a representation of enablement relations between actions. An attempt structure is only part of a more complex episode representation.

How else may actions differ cognitively? This question suggested an experimental paradigm in which subjects rate sentences (actions) as to their appropriateness for inclusion in an episode summary, followed by an unexpected recall task. Results of an initial pilot study were as follows: For summary inclusion, goal-directed actions are

much preferred over actions not specific to the goal of an episode; within the class of goal-directed actions, instrumental actions are rated higher than movement actions, which are preferred over corrective actions. As for immediate recall, goal-directed actions yield a pattern similar to that for summarization ratings. However, mishap and irrelevant actions are recalled as well as, if not better than, goal-directed actions. The latter result suggests that such actions, though not incorporated into the attempt structure, are in a more inclusive episode representation. Such actions can be considered potentially important in determining intent of a narrative. Research confirming pilot study results is needed.

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Table 1

Table 2

An Episode Representation Grammar

Rule 1: Episode   -> Problem Solution
Rule 2: Problem   -> Situation Event Goal
Rule 3: Situation -> STATE*
Rule 4: Event   -> ACTION | OCCURENCE
Rule 5: Goal   -> STATE | ACTION
Rule 6: Solution -> Attempt*
Rule 7: Attempt   -> ACTION | (Preaction* ACTION)
Rule 8: Preaction -> ACTION | (Preaction* ACTION)

* Indicates one or more occurences of the associated element.
| Indicates alternative elements.

Mean Acceptability Ratings

One-chain Episodes

	Distance		
Episode	-2	-1	0
JOHN	1.45	1.26	1.55
MARY	1.11	1.20	1.69

	1	2	3	4	5	6
JOHN	6.22	5.72	4.97	4.79	4.27	4.63
MARY	6.19	5.00	4.78	3.97	4.08	4.33

Two-chain Episodes

	Distance		
	Same		
Episode	1	2	3
BOB	6.48	4.99	4.65
FLO	6.43	4.81	3.75

	Different			
	1	2	3	4	5
BOB	1.80	1.60	1.73	1.72	2.10
FLO	1.59	--	1.96	--	1.26

Bob had recently received a note from a friend (1) and wanted to send him a letter (2). He was in a post office (3) and had his friend's address on an index card in his shirt pocket (4). Bob went to a postal clerk (5). Then he bought a stamp (6). Next Bob put the stamp on the letter (7). Then he unbuttoned his shirt pocket (8). He took out the index card (9). Then he copied the address onto the envelope (10). Finally, Bob mailed the letter (11).
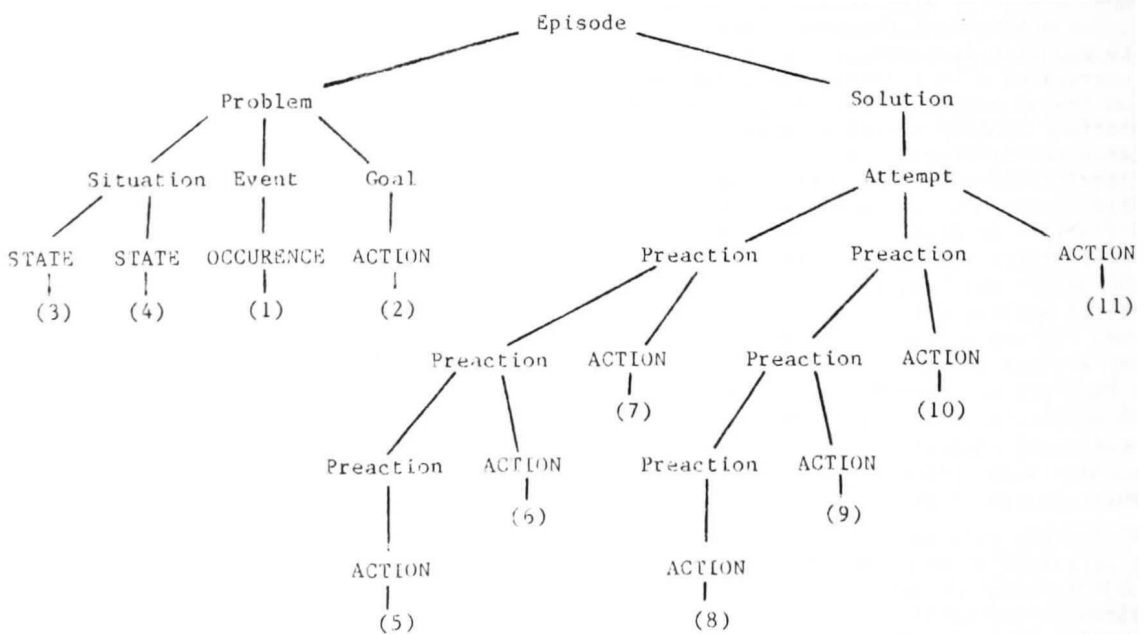

Figure 1 An Example Episode and its Representation