
Coherence and Connectivity

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COHERENCE AND CONNECTIVITY

In this paper we discuss one approach of artificial intelligence (AI) research on natural language processing that we believe will shed light on questions about coherence. Specifically, we think it will help us understand the factors that determine whether an understander will find a given text or input coherent or incoherent. The central theme of such research is that understanding and generating language are complex cognitive tasks that involve a number of interacting mechanisms and processes. Many, if not all, of these processes occur below the level of conscious awareness. The underlying methodology of such research approaches these processes by trying to specify and construct computer models of the mechanisms that are responsible for their operation. Coherence and incoherence are best understood in terms of the operation of such mechanisms.

Communication being what it is, there will be instances in which our understanding mechanisms do not operate successfully. For any given instance, we can distinguish among three possible sources of unsuccessful operation: (a) the mechanisms responsible for such processing do not operate properly, (b) the information structures that these mechanisms require are inadequate for the given task, or (c) the appropriate mechanisms have been provided with inappropriate input.¹ A text will be incoherent for a hearer when some subprocess of the larger understanding process has failed to operate successfully because of one or more of (a)–(c), and the larger process cannot continue normally because of this failure.² As we see it, incoherence is a blanket notion covering some particular set of dysfunctions in the submechanisms of the understanding system; coherence is no more than the result of their smooth operation. We find a text coherent when our understanding processes run smoothly.

Most of our discussion will focus on the coherence of narrative texts. This has the effect of doubly restricting our scope. First, since texts are primarily linguistic entities, our theory will only have direct application to linguistic coherence. Second, narratives are but one of many forms of linguistic communication. We will not explore the special conditions that account for coherence in conversations, arguments, and so on. The reason for this last restriction is that narratives seem to be the simplest types of discourses to

deal with. There is typically one speaker with one story to tell, and the connections between the parts of the story are usually tolerably clear. Compare this with the analysis of an argument involving two or more interlocutors: each having his own goals, beliefs, plans; each constantly revising his strategies and tactics on the basis of what the other says; and so on. There is at present exploratory work being done on arguments, conversations, etc., but we understand more about the way narrative processing works, and it seems likely that what we know about narratives will form the basis for the analysis of these more complex sorts of interaction.³ To gain these advantages, we have had to limit ourselves to the analysis of narratives that are quite short, quite uniform and quite commonplace. We will have little to say about the coherence or thematic unity of large scale works (e.g. novels, epic histories, etc.).

Despite these restrictions, we hope that the framework we have adopted can serve as a basis for a broader understanding of coherence as it applies beyond narratives and beyond language. Although the precise details of the ordinary usage of the term 'coherent' will not concern us here, one cannot help but notice that it does have a wide colloquial application. Among the things that can be coherent are isolated utterances, narratives, conversations, ideas, plots, arguments, positions, sets of beliefs, and much else. Notice also that the term 'understand', which is closely bound up to matters of coherence, can be applied to the subject's relation to language as well as to his relation to the world. Our view, which we will not defend here, is that an account of coherence as it applies to language will be but a specific instance of a more general account.

I

Our basic idea is that at the most general level the central relation to be explained is the coherence of an input for an understanding system. The explanation will be in terms of the understanding system's *conceptualization* of the input.⁴ At this level of generality, the concept of coherence is relevant to anything we might take to be an understanding system (e.g. human, Martian, computer, etc.). If we limit the scope of our inquiry to the human mind, we can ask about coherence as it relates to language, ideas, visual displays, musical compositions, and so on. The specific theory will then have to be articulated in terms of the special sorts of conceptualizations appropriate to the system and input under investigation. In order to construct a full-fledged *theory*, one must discover the structure of the underlying conceptualization that is relevant to the input under study (e.g. how narratives are represented), the cognitive processes involved in its

construction, the types of relations that hold between different conceptualizations, what counts as an ‘adequate conceptualization’ for the system in question, and so on.

On the theory we will put forward, the property of the hearer’s underlying conceptualization crucial for understanding coherence is its connectivity. We accept the conventional wisdom that coherence and connectedness are pretty much the same thing. Our pretheoretic bias is that something is coherent if it ‘hangs together’; if it is unified. Understanding coherence is really a matter of exploring this truism. For us this involves an analysis of the various sorts of connectivity that play a part in the hearer’s evolving mental representation of the narrative. In this section we will discuss the different types of relations that could hold between discrete parts of a conceptual representation of a narrative, and illustrate how these relations function in making the narrative coherent.

Before we turn to this task, however, we must first draw a very general distinction between two very different sorts of connectivity. The first involves the internal connectivity of the hearer’s representation of the text. Let us assume, for simplicity’s sake, that there are conceptual units with which the hearer represents the sequential parts of a narrative. The internal connectivity of the representation is simply a function of the connections that are represented as holding between these smaller units. These connections glue together the representations of the parts of the narrative into a unified representation of the whole.

A second, different sort of connectivity concerns the integratability of this unified representation into the hearer’s preexisting conceptual framework. Here the connection is ‘external’ to the representation: it holds (or fails to hold) between the hearer’s representation of the present input and his world knowledge (taking the latter notion broadly as all the information that is stored in the hearer’s long-term memory). This distinction is reflected in the difference between (1) the condition in which a person’s pronouncements are so obscure or confused that we have no real idea of what he is trying to say, and (2) instances where we can determine what the message is, but where the message makes no sense from our point of view. In the latter cases, we know what’s been said (so to speak) but we don’t know what to make of it. Real understanding involves both these interdependent processes – viz. building a conceptualization and integrating it into one’s own conception of how the world is. In this paper, however, we focus only on the first sort of connectivity.

A text is coherent for a reader if and only if the reader has constructed an adequate conceptualization for it. A given conceptualization is ‘adequate’ if and only if it is well-formed in the system’s conceptual format. The well-formedness we have in mind is to be determined by the internal criteria

of the understanding system in question. Finding something coherent is not a matter of getting it right but only of being able to make something of it. Adequacy, in this sense, is a formal notion: whether a conceptualization is adequate depends on its ‘shape’ or form, and not on its degree of fit with what it is supposed to be a conceptualization of. An example might make this point clearer. If our conceptualization of ‘John went from Bill’s house to Tom’s was:

$$(1) \quad W(j, h, h)$$

then the following sort of rule would deem it inadequate

$$(x)(y)(z)(Wx, y, z \rightarrow \sim(y = z)).$$

This constraint corresponds to the requirement that only movings to other places count as goings. This rule is formal in that it’s application does not depend on (e.g.) whether the John the speaker had in mind is in fact the person that ‘*j*’ represents for the hearer.

The adequacy of the constructed conceptualization is at most a necessary condition for understanding, but it cannot be sufficient. One consequence of our theory is that there can be inputs for which a hearer will construct an adequate conceptualization but which he will not fully or ‘really’ understand; he may *think* he understands but he really *misunderstands*. Again, whether a hearer understands a given input is more than simply a formal matter; it involves a semantic property – i.e. the match between the speaker’s communicative content (and perhaps at times his intent as well), and the processes that go on in the hearer.

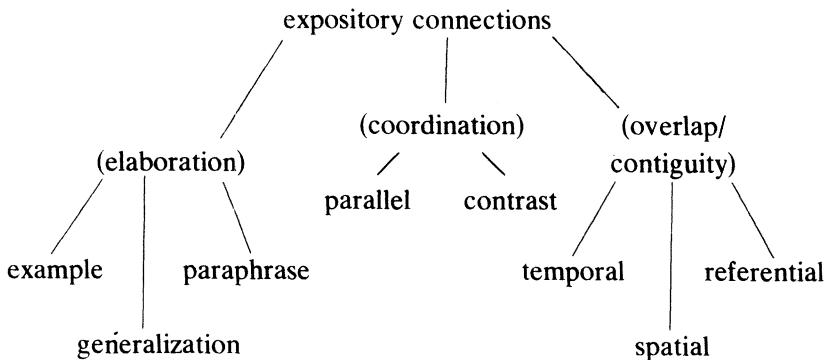
II

We have claimed so far that coherence depends on the adequacy of the conceptualization, and that such adequacy, in the case of narratives at least, is a function of the interconnectedness of the parts. We now turn our attention to the different sorts of connections that unify the conceptualization of a narrative, and to the structure of the understanding mechanisms that enable the understander to determine that these connections hold.

Intersentential connections. Let us assume we are dealing with a narrative that contains no incoherent segments. If the whole is nevertheless incoherent for a given hearer, the likely cause is that he cannot make the higher level conceptual connections between the meaningful sentences, paragraphs, etc. The representation of the whole turns out to be more than

the sum of the parses of the individual parts. In this section we will look at a number of the intersentential links that help glue a narrative together. We can distinguish two ways that representations of parts of a narrative can be connected, based on two different sorts of relations that can hold between the parts. We can characterize these connections as *expository* and *interpolative*.

Expository connections. Some of the expository connections that can hold between elements in the representation of a narrative are presented in the following tree:



The list may no doubt be extended, and there are many improvements that can be made even within these categories and subcategories.⁵

We can see these connections exemplified by imagining a hypothetical narrative fragment that begins with (2):

- (2) The heads of the city's uniformed services polished their contingency plans for a strike.

and continues with one or more of the (3)–(10):⁶

- (3) The Fire Department (which is the largest of the uniformed services), issued safety guidelines that the public should follow. (EXAMPLE)
- (4) Officials throughout the municipal administration (have joined efforts with the heads of the city's uniformed services and) are preparing the city for this contingency. (GENERALIZATION)
- (5) (As district representative David Geiger put it) 'Leaders of the fire, police, and sanitation departments are working on

alternative procedures to be followed in case of a labor stoppage'. (PARAPHRASE)

- (6) (By the same token), residents across the city planned for the prospect of reduced services. (PARALLEL)
- (7) Union leaders, (on the other hand), remain implacable and seem unperturbed at the prospect of a threatened federal injunction. (CONTRAST)
- (8) (Just a few hours earlier) negotiators had seemed hopeful that a strike could be averted. (TEMPORAL CONTIGUITY)
- (9) The noise from a party (in the next suite at the Waldorf Astoria) hosted by the UN representative from Peru did little to alleviate the tension. (SPATIAL CONTIGUITY)
- (10) It was not too long ago that this group (made up of the heads of the city's uniformed services) pledged to work with the unions in redressing contract imbalances. (REFERENTIAL OVERLAP)

In many of these cases there is a plausible inference that the hearer has to make in order to connect (2) to one of the subsequent statements. For the sequence (2)–(3) to make sense one must assume that the fire department is one of the city's uniformed services. If (9) follows (2), then one must conclude that the preparations are being made very close to the party (in this case there may be a strong causal connection operating as well). The parenthesized expressions are just a few of the linguistic devices available for telegraphing the sorts of connectivity the speaker takes to hold between the utterances, and sometimes speakers alleviate the inferential burden on hearers by making these relations explicit. Generally, though, these explicit links are unnecessary – most hearers can determine the relevant connections without them. To the extent that the hearer cannot figure out these connections, he will find the text incoherent – e.g. What does the Peruvian ambassador have to do with the strike preparations? Clearly, not all hearers are alike in their ability or in the background knowledge required to see such connections.

Although these connections do play a part in the understanding process, in our view they only fulfill a support function. We have to distinguish between the *expository continuity* of a narrative text, and its *narrative coherence*. Types of communicative settings are governed by conventions that partially determine the forms of linguistic behavior most fitting to that

setting. We can assume that these conventions are shaped by the intended goals of such exchanges. In the case of narratives, much work has been done by literary theorists in an attempt to uncover these structural principles. It seems plausible that most of the expository connections (especially those on the left and middle branches) contribute to the expository continuity of the narrative. These connections have more to do with the structure of the exposition of narratives than with the substance of the story line itself.

This distinction between expository continuity and narrative coherence reflects a more critical difference between the types of connectivity that contribute to coherence. A narrative is a sequence of utterances that tells a story. We can think of some elements of the sequence as belonging to the core of the story and others as amplifying and embellishing this core. Colloquially we often mark this distinction by contrasting the ‘gist’ of the narrative, on the one hand, with the scene setting, elaborations, and so on, on the other. The hearer’s understanding mechanisms are sensitive to the fact that not every piece of the narrative introduces the next sequential event that will take the story line further into the future. Some elements will redescribe events already introduced, others will clarify the relation between previously introduced events, some will foreshadow events that might occur at some later point, still others might comment on unactualized possibilities, on aspects of character, and so on. Unless hearers could exploit such information, most narratives would seem interleaved with unrelated distractions. Seen in this light, the expository connections comprise the possible relations between the peripheral elements and the narrative core.

To see that such connections are relegated to this support function, we only have to consider mock narratives that exhibit these connections but ‘make no sense at all’ – i.e. are inarguably incoherent.

- (11) The heads of the city’s uniformed services polished their contingency plans for a strike. Queen Wilhelmina finalized her own plans for the evening. In a nearby Danish town, two fishmongers exchanged blows. Anders, by far the stronger, had a cousin in prison. Many criminals are in prison; one might say that a good number of those individuals who have violated the penal code are incarcerated . . .

We can figure out what each of the sentences in (11) means, and we can determine, for instance, that one of the battling fishmongers and the Anders whose cousin is locked up are one and the same – i.e. there is some referential overlap. All of the sentences, in fact, are connected to their

predecessors by some expository relation or other. Despite all this, there is something lacking that the introduction of more expository connections will not remedy. In cases like this one, what is missing is a center – there is no story-line, plot, ‘thread’, etc. – around which the discrete parts come together as a narrative. There is no determinable point to (11). There may be commentary, but there is nothing to comment upon. The important point is that our ability to render certain elements of a text understandable by using these expository connections cannot itself make a text coherent to the point of making sense.

This last point has often been missed. To take one example, the theory suggested in a paper by Kintsch and van Dijk (1978) treats coherence wholly in terms of what we have called ‘referential overlap’ and it fails for just this reason: one can generate sentence after sentence about Anders the battling fishmonger and his coterie, as in (12) and never end up with anything coherent at all.

- (12) In a little Danish town, two fishmongers exchanged blows. Anders, by far the stronger, had a cousin in prison. Anders was twice the age of that cousin. When he first was convicted, Anders was living in Italy. Anders has a wife who lost her bathing cap. Her car is at this moment doubleparked.

On the other hand, it seems possible to construct a narrative that does not make use of any of these connections essentially but which is nonetheless coherent. Such a narrative is bound to be stark, but can be easily understood. Consider (13):

- (13) John punched Bill in the nose, and Bill’s nose started to bleed. Bill went to the doctor who told him that his nose was broken and that resetting it would cost \$1500. Bill hired a lawyer and sued John.

It follows then that if connectivity is in fact at the heart of coherence, there must be some other type of relation that holds between the discrete parts of a narrative but which is not included in our tree of expository connections. On our view, the missing connections are the causal relations that are at the heart of the story line.⁷

Causal connectivity. Other things being equal, a narrative will be coherent for a hearer to the extent that he is able to make the causal interconnections among the parts.⁸ Insofar as he cannot compute or formulate a conceptualization of the narrative that is adequately causally connected, it will be incoherent for him. All this suggests the following analogy to guide us in thinking about coherence. Imagine that we give a

child pieces of a jigsaw puzzle, and that we want to make it easy for him to put it all together. One thing we might do is to provide clues about how the new pieces could fit into his partially completed puzzle – e.g. we could tell him the correct spatial orientation of a new piece, etc. The expository elements of the narrative are the analogues of such clues; there is no real piece of the puzzle that corresponds to them, just as there is no real piece of the story-line that the expository elements convey. Narratives should be thought of as (among other things), ways of conveying story-lines, and giving clues along with pieces is a way of presenting a puzzle to a child.

In (14), for example, there is mention of a ladder that is on the scene, but there is no event explicitly recounted in which the ladder plays a part.

- (14) Mallory lost his frisbee somewhere on the roof of his parents' garage. Luckily, there was a ladder closeby – when he finally retrieved it he decided he'd be better off playing in the park.

Nevertheless, it is obvious that the contiguous ladder is the centerpiece of the causal chain the reader is expected to construct. So besides providing for expository continuity – in the sense of providing the narrative 'flow' – these elements also support the coherence of the narrative by providing information that is crucial to the reader's causal reasoning.

Even though many children need the clues to put the puzzle together, the coherence of the puzzle is not a function of the clues that one is given. Puzzles are 'coherent' because the pieces depict something when properly put together. So too in the case of narratives: the coherence of the whole is a matter of the causally connected story-line at the center.⁹ The crucial question now becomes: How do hearers piece together the relevant parts of the narrative and build a conceptualization of this central causal chain?

Before we proceed, we have to consider the following challenge. It might seem that in likening narratives to puzzles, we are taking the determination of the causal connectivity of a narrative to be a bigger problem than it actually is. After all, narratives are not really like jigsaw puzzles. The pieces of the central causal chain are usually presented in temporal order (or at least close to that order). When they are not, there are rules and principles available to the hearer that can help reorder the relevant event representations to coincide with the order of their occurrence and causal interconnection.¹⁰ On the basis of these sorts of considerations, the jigsaw puzzle analogy might be thought a misleading characterization of narratives as 'event salads' that we have to somehow pick apart and reorder.

These misgivings are understandable, but they are based on a naive view of narrative structure, and ultimately, a naive view of the design of discourse. Let us return to one of our earlier examples:

- (3) The Fire Department (which is the largest of the uniformed services) issued safety guidelines that the public should follow.

If the narrative continued as in (15),

- (15) The Fire Department (which is the largest of the uniformed services), issued safety guidelines that the public should follow. As a result, many citizens were aware of what to do in case of fire.

the problem of determining causal connectivity would be greatly simplified. It would still not be a trivial point to explain in detail how the hearer confirms that issuance of guidelines by an agency leads to the acquisition of new information by unspecified segments of the population, but we can imagine how such a process might work. But what if the hearer has to deal with the following narrative fragment?

- (16) The heads of the city's uniformed services polished their contingency plans for a strike. How long the union's coffers would hold out was anybody's guess.

Obviously the problems involved in processing this sequence are of a different order of complexity than those encountered in dealing with (15). A partial listing: where do unions enter the picture? who is the union? what are their coffers? why are they pressured? why should anyone want to guess at the answer to the embedded question? what does contingency planning have to do with the economics of union treasuries? and so on. Of course, only some of these questions have to do with the causal connection between the two sentences, but these are difficult enough.¹¹

It should be apparent that constructing a conceptualization that make these causal connections properly is significantly more difficult than grasping and exploiting the expository connections taken up earlier. Consider our puzzle analogy again. When we deal with the expository connections, the relevant pieces of the puzzle are all given and the task of the understander is to figure out just how the pieces fit together. If one has all the pieces and knows the possible manipulations for combining them, then trying them all will eventuate in a solution (if there is one).

In understanding the causal connectivity of narratives, on the other hand, the ability to manipulate the individual pieces will usually not be enough. More often than not, pieces of the puzzle will be missing. So the competent hearer knows that the completed picture includes not only pieces he has been given, but also an unspecified number of pieces that he will have to somehow construct on his own. Computing the causal relations of the explicit parts requires that we expand the text and fill in the missing pieces.¹²

In speaking of missing pieces, we must prevent a possible misunderstanding. We have claimed that hearers must be able to reconstruct the causal connections that hold between elements in a narrative. But when is such reconstruction complete? We do not mean that they must be able to construct a causal chain that is in some scientifically determined sense ‘complete’. It is perfectly plausible to think of an understanding system that was ‘satisfied’ with causal chains some of whose links were only indirect causes or effects of their neighbors. The point is that the psychological standard of ‘direct cause (effect)’ need not be the physicist’s standard. This is simply another way of saying that representational adequacy, unlike real understanding, is to be determined relative to the system in question. To take an example: if given (17)

- (17) Johnny’s friends scattered when his line drive hit the Jones’ window. Mr. Jones came out flushed with anger and searched for the boys.

most hearers assume that the window was closed, that the ball hit the window and broke it, that Mr. Jones knows about this (and is not just angry about something else), and so on. These are not deductive consequences of the description, but they are the ‘default’ assumptions – unless the hearer is given contrary information, he can suppose all this to be so. But the hearer need not infer anything about the complex sequence of (micro)events that mediated between the batted ball striking the window and the window shattering. For most hearers, the cause and effect relation between the two events is ‘immediate’.

It seems reasonable to suppose that hearers have a ‘naïve theory of causality’ which sets these conditions of adequacy and completeness on causal explanations. Working out the details of such a theory is of course an empirical matter,¹³ but it is this naïve theory that provides the test of adequacy for conceptualizations of narratives. Looking at coherence and adequacy from this perspective, the situation is this. The reader’s conceptualization *C* is adequate if and only if his naïve theory ‘accepts’ the central causal chain represented in *C* as plausibly connected. If it is not accepted, then it is causally gappy and requires supplementation. If it cannot be supplemented, then it is adequate. If it is inadequate, then it is not coherent for the reader.

III

We can now return to our earlier question: How is this supplementation achieved? What is the nature of the psychological mechanisms that

mobilize our world knowledge and enable us to interpolate hypothetical events into a ‘gappy’ chain? We can begin to answer these questions by taking another look at the range of the examples. We have already considered some of these, the others present new problems of their own.

- (15) The Fire Department issued safety guidelines that the public should follow. As a result, many citizens were aware of what to do in case of fire.
- (16) The heads of the city’s uniformed services polished their contingency plans for a strike. How long the union’s coffers would hold out was anybody’s guess.
- (17) Johnny’s friends scattered when his line drive hit the Jones’ window. Mr. Jones came out flushed with anger and searched for the boys.
- (18) Larry went into a restaurant. The baked salmon sounded good and he ordered it.
- (19) Thelma was very hungry. She looked for her Michelin Guide.

The first two examples are at nearly opposite ends on the spectrum of processing complexity; (17)–(19) fall somewhere in between.

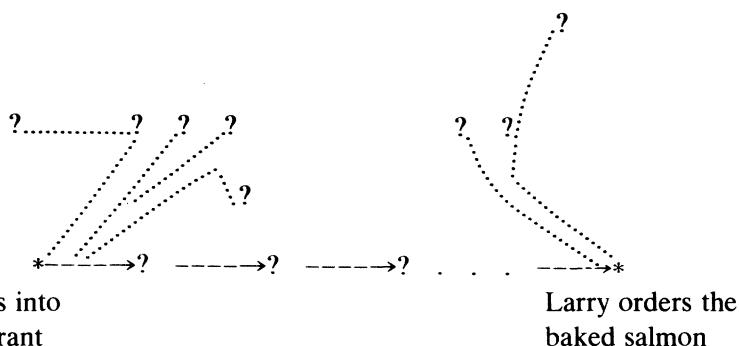
The causal connections in (17) are a bit rococo: on one plausible version, event *A* (= the ball hits the window) causes *B* (= the friends scatter) – or, perhaps better: *A* causes *A'* (= friends anticipate *D* and *F*), *A'* causes *A''* (= the friends get scared) and *A''* causes *B* – and *A* also causes *C* (= the window breaks); *C* causes *D* (= Mr. Jones gets angry); and *D* causes *E* (= Mr. Jones flushes) and *F* (= Mr. Jones searches for the boys). All these events are mentioned in the text, but their connections are somewhat obscured by the syntax – event *A*, for instance, only appears as the temporal parameter on event *B*.

In (18) a number of intermediate events are not mentioned at all: we expect that Larry was seated, looked at a menu, spoke to a waiter (or waitress), etc. Notice that these events include objects and characters that are never explicitly mentioned, and yet we assume that they are there. There is strong psychological evidence indicating that memory representations for such stories often do contain much of this inexplicit information, and there is interesting linguistic evidence that points in the same direction: it is significant that in some later part of the narrative we can introduce these objects and characters using the definite article – as *the* menu, and *the* waiter – even though they have never been explicitly mentioned in the text.¹⁴ Notice also that a naively ‘literal’ reading of (18) might lead to the conclusion that there is more that needs to be connected than there actually

is – e.g. that the baked salmon was emitting pleasant sounds, that there is one specific salmon that appealed to Larry (as opposed to a certain type of dish), and so on. There must be some way the hearer avoids these interpretations; there is some reason to doubt that they are ever even entertained as possible readings.¹⁵ In (19) the causal connections to be determined depend on the hearer's naive theory of motivation – i.e. psychological causation. The events that the hearer must reconstruct are those that connect Thelma's hunger with her search for the Michelin Guide – viz. the cognitive processes that subtend plan executions.

Let us start with (18) and try to produce a rough sketch of how the causal connections are determined. The hearer is first told that Larry entered a restaurant; to simplify matters, we can guess that on the basis of what the hearer knows about people (they get hungry), restaurants (they dispense food), and hunger (it is satisfied by food), he expects that the reason Larry went in was to get something to eat. He can also search his long-term memory for information about restaurants and discover that they usually offer a number of options regarding what one eats there. Again, given what he knows about people (where there are options there is likely to be a decision process that selects among the alternatives) he can determine that Larry will have to make a choice. In order for him to make such a choice he must first find out about the alternatives. Hearers know that this sort of information is conveyed either in the form of a written listing (menu, blackboard, etc.) or orally. In either case, there will be someone who presents the alternatives and relays the choice to the kitchen Eventually, this sort of process might lead to the construction of an adequate conceptualization of the episode described: i.e. one that reflects the fact that Larry wanted to eat, went to a restaurant, selected the baked salmon, ordered the baked salmon from the waiter, and so on.

The chain of reasoning outlined in the last paragraph seems to get the job done, even though it is somewhat cumbersome. What is more to the point, however, is that we have rather cavalierly assumed that the right inferences will be made at every step along the way. As we said near the start, a full-fledged theory of coherence for a domain will have to say something about the underlying processes that control such reasoning. Since simply specifying the steps in the chain – the output of such a process – says nothing about the procedures that determine the steps, it is wholly inadequate as an explanation of how such causal reasoning is carried out. If we represent the reasoning problem as one of describing a set of procedures for constructing a set of intermediate events to be placed between the endpoints of this causal chain, we get a more realistic view of the complexity of the task: how do we discover a plausible path between the two points?



The problem is of course most acute in examples like (16), but there are plenty of ways to go astray in dealing with even a relatively obvious example like (18). From the fact that Larry entered a restaurant, we can infer any number of things that ultimately will have nothing to do with the connections that hold between entering and ordering. We can infer that if he entered the restaurant, he is now inside it. If he is now inside it, then he can make use of the various facilities inside the restaurant. One thing we know about restaurants is that they have restrooms. So Larry can go to the restroom. If we like, we can now begin an analogous process working backwards from the endpoint. If Larry ordered the baked salmon, then it must be one of the things that the restaurant is prepared to serve. But this must mean that they have some baked salmon. If they have baked salmon, then they must have bought it or acquired it in some way or other. Since salmon are fish, and fish live in the sea, the restaurant could have caught it. But you only catch salmon if you fish for them, and our knowledge about restaurants precludes the possibility that they can fish; only people can do that. If the fish was caught for the restaurant, then it must have been caught by some individual who was an agent of the restaurant, and so on. It is clear that such undirected flights of inference will not do. Although we've constructed partial chains leading away from the initial and endpoints, we are getting nowhere in our attempt to connect them. We could, if we liked, add that people who go out fishing must (like everyone else) have need of a restroom, but this way of connecting up the endpoints does not give us a causal chain; all we have is an odd sort of 'stream of consciousness' associative string. What we've got might have been just the right chain of inferences for some other narrative, but it is of little use in understanding (18). We cannot begin to make random inferences on the basis of what we know about people and restaurants, and expect such a procedure to be useful in understanding causal connections.¹⁶

Notice that we are not claiming that this sort of procedure for

determining causal connectivity is logically impossible. Perseverance might very well yield an acceptable solution. The important point is that this method of chaining is hopelessly inefficient and not psychologically motivated. If it is used at all, it will only be used as a fail-safe method (or in a tightly controlled way – e.g. go only three steps, etc.). In constructing explanatory models of psychological processes – and we naturally take determining causal connections to be part of the understanding process – we have to provide more than a logically impeccable procedure. The processes proposed have to meet criteria of computational feasibility as well. It is a crucial fact about the understanding process that it is fast; hearers are rarely conscious of any time lag in the transition from hearing to understanding. A realistic model of this process will have to match not only the normal understander's accuracy – it is rare that we misunderstand the connections in any of the examples of narratives we've considered – but also his efficiency.¹⁷ We don't want to put too much weight on these points about speed, but if our model can do no better than to try making more or less random inferences and hope for the best, it will run into what computer scientists call the problem of 'combinatorial explosion'. From a small set of inferences, the set of possible continuations grows very quickly. We therefore need some way to constrain or direct the inference process so that irrelevant inferencing along hopeless paths is cut to a minimum and relevant pathways are pursued. Avoiding combinatorial explosion, in one form or another, has long been recognized as a central problem of AI research.

To be accurate, we should say that there is not one problem here, but many. Human cognizers do avoid combinatorial explosion, but the way they do this may differ considerably from domain to domain. Certainly knowledge about the domain and the context will help. But what makes for efficient processing of visual input, for example, need not be identical (in any detailed way) with what accounts for the ability to understand narratives. We might suspect that the radical differences will disappear at some higher level of description; perhaps both can be viewed as different implementations of the same abstract strategy.¹⁸ Methodologically, however, we cannot begin with such broad generalizations. We need to get a clear picture of some cognitive domains, specified in terms of specific sets of mechanisms and processes, before we can speculate about any general principles that might govern cognition. Our concentration on understanding, and specifically on the ability to discover and represent the causal connections that obtain in narratives, is an attempt to discover the design of one such system. We would like to say that we have solved the problem at this more specific level, but we have not. What we have developed over the

past few years are ways to cut this problem down to size a bit. In what follows we will present an overview of a few of the basic theoretical notions that have been developed and the programs that embody them.

IV

Scripts. Let us return to (18). We have hypothesized that understanding such narrative sequences involves the application of a ‘script’ – in this case, a ‘restaurant script’. A script is a packet of information (what in computer science is generally referred to as a ‘data structure’) that contains representations of a set of events (really: event-types) that typically occur together in a more or less fixed order. The restaurant script, for instance, is arranged in the form of a series of ‘scenes’: the entering scene, the ordering scene, the eating scene, the paying scene, and so on. When we hear a story about someone going into a restaurant, we don’t have to make low-level inferences about what the consequences of entering a place are, what restaurants are for, etc. What happens is that our restaurant script is activated, and serves as a skeleton conceptualization whose slots only need to be filled in. Since the speaker knows that we have such a script available, he doesn’t have to run through all the obvious details of what happened to Larry when he went into the restaurant. All he has to do is provide the explicit information that will enable us to flesh out the specifics of these scenes.¹⁹

Script-based understanding systems have a number of advantages.

First and foremost, since the causal connections between many of the relevant events in a script are in some sense ‘precomputed’, the computation task at the time of understanding is reduced drastically.

Second, scripts help explain how hearers make inferences about events and objects not mentioned explicitly in the narrative. Our conceptualization of ‘John stopped for a bite’ includes a restaurant, waiter, food, etc. because these are the defaults of the restaurant script – we assume these items played their normal role because there was no mention of them not doing so.²⁰

Third, scripts can help explain how we understand specific sentences like “The baked salmon sounded good and he ordered it”. We could imagine an understanding system that constructed and entertained a number of semantic readings for this sentence: e.g. that the baked salmons sang well and Larry therefore decided to eat one, that a specific baked salmon had the good voice . . . , that a baked salmon sang well and he ordered it (perhaps to stop singing?), that the meal offered as ‘baked salmon’ appealed to him and he told the waiter that he wanted to eat one, etc. We can imagine

a system that runs through the possibilities (there are quite a number) and perhaps comes up with the right one, but scripts make this unnecessary. Once the hearer is ‘in’ the restaurant script – that is to say, once this data structure has been activated and is playing a role in directing processing – the hearer is looking to fill the slot in the ordering scene, and the slot is marked as taking the name of a food. Furthermore, there is no room in the script for the actor to command the food to do anything, so the semantic representations that take this reading of ‘ordered’ will normally never get constructed.²¹

Fourth, there is hope that a script-based system of understanding will have application outside the realm of text understanding. We not only read and hear about script-like activities, but we also do such things. We know what to do in a restaurant because information about what is typical about trips to a restaurant is stored in memory in such a way as to be accessible as a structured whole. It seems reasonable to conjecture that these are the same prepackaged chunks of information used in understanding narratives about restaurants – i.e. a restaurant script. This should recall our earlier conjecture that what accounts for the coherence of stretches of language is but a particular instance of a more general phenomenon.

Fifth, and this point extends the last one, scripts seem to have an important part to play in the organization of episodic memory.²² It is reasonable to think that the knowledge structures that facilitate understanding of restaurant-related materials also serve to organize the representations of specific restaurant episodes in long term memory.

This is an oversimplified account of how a script is used in understanding, but it does serve to bring an important point into sharper focus. To a large extent, understanding is a predictive process. The parts of a narrative that we’ve already processed and the context in which the narrative is produced create strong expectations as to the general form of what is coming next. These expectations provide one key to the issue of directing inferences – our knowledge about the world narrows our attention to a small set of inference paths which we will actively pursue at any given point in the understanding process. Scripts should be thought of as one type of knowledge structure that provides this sort of direction.

Although script-like data structures are important in understanding – especially in the case of narratives – script-based understanding is at best only one component in a much more complex system. Some of the reasons for this should be obvious. In the first place, not all narratives involve scripts in any essential way. When you hear that the president’s brother has been accused of improprieties involving a foreign government, you probably have no script available that handles just this sort of situation. To be sure,

you have strong expectations about what you will hear next (e.g. vehement denials from all parties directly concerned, overblown accusations from representatives of the other political party, calls for a government investigation, and so forth), but there is no scene-by-scene guidebook that you fill in as you get more details. What this indicates is that there must also be more abstract knowledge structures that facilitate understanding of such narratives.

But it is not just that some narratives are not governed by a detailed script. The point is rather that even those stories that are script-like are only partially so. A narrative about a person who went to a restaurant, was seated, ordered, ate, and paid, is not usually very interesting. In most stories, such a script will be most useful in providing the background knowledge that sets the stage for the non-script-like items – e.g. when the narrator tells us that the proprietor demanded that he take his llama out the back door, we don't have to puzzle over who this previously un-introduced 'proprietor' might be; the script makes that clear (he is an 'extra' so to speak). But this script cannot help us figure out what the llama is doing in the restaurant. To the extent that a narrative can be understood using only a script, it will be stereotypical and deadly dull; much like every fisherman's story about the big one that got away. Unless the narratives we are interested in understanding are extremely regimented, both as to the types of situations they describe and the types of information about such situations that they contain, scripts will not tell the whole story.²³ Many stories encountered do not follow much of a script at all, and very few are completely understandable in terms of a script. This inability to deal with novel situations demarcates the limit of script-based understanding. Scripts, then, can only be one of many factors involved in understanding the type of causal connectivity that is crucial to coherence of narratives. We have to look for other types of knowledge structures that can cut the problem down further.

Plans and Goals. One such structure is suggested by (19):

(19) Thelma was very hungry. She looked for her Michelin Guide.

This fragment resembles (18) in content, but only involves the restaurant script peripherally. Although people sometimes go to restaurants when they are hungry, finding out that someone was hungry does not immediately lead us to assume that they are going to a restaurant. On the basis of the first sentence alone, we cannot make any concrete predictions about what Thelma will do next, where she will go, and so on (unless we have some other background information about her). The options available to a hungry person are simply too varied. The first sentence should therefore not direct

us to any script-like prepackaged sequence of ‘scenes’ that we will then use to understand what follows. But notice that our knowledge about hunger creates strong expectation about Thelma’s motivations and subsequent action: we expect that she has a certain motivation, and that, all things being equal, she will try to do something to alleviate her hunger. These expectations about her behavior create expectations about the subsequent parts of the narrative. We anticipate references to actions that are parts of plans in the service of this goal (to satisfy her hunger) that we hypothesize she has. Intuitively, it is this expectation that guides our interpretation about the search for the Michelin Guide.

Here is a rough sketch of a process that might partially explain how this fragment is understood. Hearing that Thelma is hungry leads to a particular goal-asccription – i.e. that she wants to be in a state of non-hunger. Once we’ve hypothesized that she has this goal, subsequent event descriptions will be processed to see if they can be interpreted as referring to implementations of a plan to reach the goal. We then hear that she is looking for a book. Since looking for a book does not in itself satisfy hunger, we have to assume (by default) that she is looking for it with the aim of finding it (looking is part of a typical plan in service of finding, which serves as an embedded sub-goal). Finding it will still leave her hungry, so we infer (again by default) that if and when she finds it, she will want to do what people normally do with books – i.e. read them to get information out of them. Since we know that eating (but not reading) is the temporary cure for hunger, we can infer that the information she wants probably has to do with getting food to eat. Using knowledge about the type of book she is looking for (e.g. a guidebook, not a cookbook), this process will enable the hearer to understand that Thelma wants to know the location of a restaurant. Since this in itself does not constitute a satisfactory plan for dealing with hunger (the endpoint of the plan does not match the hypothesized goal), the hearer must infer that Thelma wants to go to a restaurant in order to eat there – i.e. instantiate the restaurant script.²⁴ Something like this process also helps explain why most hearers find fragments like (20) perfectly coherent,

- (20) Thelma was hungry. She looked for her Michelin Guide, and eventually ended up at Lutece’s.

even if they don’t know that Lutece’s is a restaurant. No one puzzles over the fact that Thelma’s search for her book should end in a French restaurant (consider the following comments: “What a happy coincidence, since she was already hungry when she started looking!”, or “That’s strange, did she leave it there?”).

What controls this understanding process – what keeps it on the right path

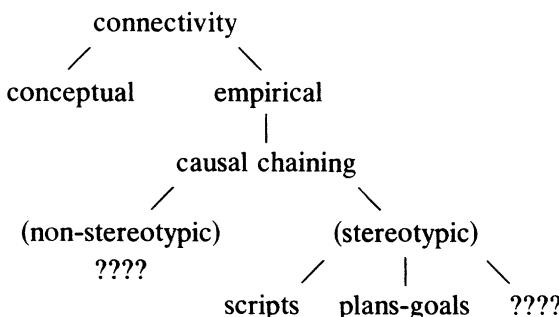
– is the set of expectations generated by the knowledge that (i) Thelma is hungry and (ii) dishunger is a universal goal (almost). The expectations are available because they are triggered by precomputed plans for frequently occurring goals. Our research suggests that when presented with a fragment like (19), the reader constructs a representation of each character's active goals, what plans are used to achieve those goals, and how the various goals interact. It is as if we were approaching new linguistic inputs of this sort with these implicit questions: can this new input be understood as referring to part of a plan to achieve an active goal? Does it introduce a new goal? Our answers to these questions provide the elaborations required for an understanding of (19) as a network of causally related events, only some of which are explicitly mentioned. The representation of the narrative at this conceptual level is an instantiated data structure that connects (some of) the specific events described as actions taken in pursuit of an end state. And it is this underlying goal-pursuit representation that gives the narrative the coherence it has.

Understanding and representing narratives in terms of the plans and goals of the characters has many of the advantages and limitations of script-based understanding. On the plus side, hypotheses about motivation act like scripts in directing inferences: where scripts lead us to expect instances of specific event-types, plans lead us to expect events with specific sorts of consequences – steps along the path to a goal. It would seem that most of the points made earlier in regard to scripts and parsing, scripts and the organization of memory, scripts for understanding vis-à-vis scripts for acting, etc. hold for plans and goals as well. On the minus side, goal-based processing also often only provides a backdrop for a narrative that is not essentially about individual goals. For instance, we understand why the character went to the stockroom in “I had run out of chalk and walked into the stockroom; would you believe I saw this guy with glasses putting on a Superman costume!?” by attending to his plans and goals, but if this remains the focus of our attention we will miss the point of the anecdote.

One thing that emerges from looking at these two particular sorts of knowledge structures – scripts and plans-goals – is that the processes that account for our ability to represent the causal connections in narratives must interact. Scriptal elements of narratives are processed in one way, while those elements involving the intentionality of agents and their actions are handled slightly differently. The results of one subprocess must be available to other submechanisms involved in processing the same material (e.g. the knowledge represented in the restaurant script is accessed in the inference that Thelma looked for her Michelin guide as part of a subplan of locating a restaurant). More generally, we can say that the design of

understanding seems to involve a partnership of various specialized contributors, with no one specific type of knowledge structure assigned to provide *the* framework for understanding.

This point about interacting cognitive structures must be extended beyond the narrow domain of comprehension of narratives. If we are right, then certain sorts of causal links between events are of paramount importance in the representation of narratives.²⁵ But as we said at the outset, this hypothesis about how narratives are processed should not automatically be extended to the processing involved in other forms of discourse. Consider instructional texts (recipes, assembly instructions, spatial directions, etc.). Here the basic connections are not exactly the causal links between the steps; it is more the contribution that the ordered execution of each step makes toward some specific end. In this sense, understanding instructions is something like understanding narratives that deal with implementations of plans to reach goals. If we turn our attention to arguments (both theoretical and practical), then our processing mechanisms have to be especially sensitive to the *conceptual* links between the parts: evidential relations, justification relations, attack relations, shifts of focus, and so on.²⁶ The long-term project of constructing a comprehensive theory of natural language understanding will have to encompass all these discourse types, and deal with the fact that they more often than not overlap in most actual discourse. There are narratives about arguments, arguments about instructions, and so on. In terms of the various types of connectivity that are of importance for an understanding of coherence, our analysis has only addressed some of the material on the right branch.



V

Our work in this area points us in two directions. As we stated earlier, script-like understanding has its limitations. The critical fact is that it is only

cognitively efficient to store prepackaged schemas for those events and goal pursuits that occur fairly regularly. Since most narratives are not stereotypical in this way – characters do more than ‘go through the motions’ – we still have to explain how hearers can find extremely novel stories coherent. To return to one of our earlier questions: how do we model what is involved in understanding (16)

- (16) The heads of the city's uniformed services polished their contingency plans for a strike. How long the union's coffers would hold out was anybody's guess.

without letting the inferential processes get out of hand?

On the other hand, although we at present have no ready answer to this question, the research we've been discussing suggests that in order to make progress we must shift the focus of our attention slightly. Our original research goal was to simulate understanding of specific linguistic materials. What structures like scripts and plans have shown us is that certain sorts of processing are possible because our memory²⁷ contains precomputed large-scale structures that act as guidebooks for understanding. So even though scripts do not tell the whole story, they provide an important clue as to how the rest of the story might unfold. They suggest that the key to understanding is the effective organization of memory.

Until now, we have concentrated on scripts in terms of their role in understanding certain sorts of narratives. But to be of any value, they must be more or less stable structures in memory that are readily available for application to specific sorts of linguistic inputs. But now if we put aside the linguistic inputs for a moment, it becomes plain that the script hypothesis is also a hypothesis about the organization of memory – i.e. we are claiming that a hearer's long-term memory contains knowledge structures of a particular sort. It is now reasonable to ask about the possible uses of such high-level structures *apart* from their role in language processing. This should bring to mind our earlier conjecture about the potential flexibility of script-like structures. We might speculate that scripts are useful in understanding stories about restaurants because they also help to structure the mass of information that we have available about restaurants. Something like a skeletal script might be the structure within which we store specific episodic memories of restaurant experiences, particular facts about individual restaurants, and high-level knowledge that applies to restaurants in general. If scripts are what we learn when we learn about restaurants, what guides our experiences in particular restaurants, and organizes our long-term knowledge about restaurants, then it is natural that they should provide the basis for understanding narratives about restaurants.

The moral we want to draw from all this is that we should look for the same multipurpose flexibility in other memory structures. In order to understand how we process nonstereotypical texts – how we deal with inputs we were not totally prepared for – we need to know more about other types of frameworks and structural schemas that are involved in the organization of memory.²⁸ This moral extends to our understanding of coherence as well. To develop a theory of how hearers find narratives coherent, we first have to learn more about the general organization of the memory information that is brought to bear in the conceptualization process. Although the ordinary hearer probably doesn't have a script that enables him to causally connect the strike preparations with the speculation about union coffers in (16) (labor negotiators probably do), there is something about the way his knowledge about unions, strikes, solidarity, sustenance, etc. is structured that allows him to access the appropriate piece of information at the right time and make the inference easily.

To get at this something, we have to learn more about the overall organizational possibilities of memory: what sorts of structures can we use to store information efficiently? how can these structures be connected? what sorts of search procedures are available for accessing different structures? and so on. We have to develop a theory that can give a detailed explanation of why *The War of the Ghosts*²⁹ is incoherent (as it stands) for most Americans but may be found coherent by many Eskimos. To effectively model understanding, therefore, we must design algorithms that will find narratives coherent or incoherent depending on the particular memory base employed. In the end, then, progress in understanding coherence depends on progress in understanding the organization of information in memory.

NOTES

¹ By 'input' and 'output' we do not restrict ourselves to the environmental stimulus and the behavioral response; we include the operations that are internal to the understanding system. The input to one subprocess (e.g. the string parser) could be the output of some other processing mechanism (e.g. a sentence token determiner) and the output (again, of the parser) might be the input to yet another internal subsystem (e.g. the one that stores information in long-term memory).

² It seems reasonable to assume that sometimes a subprocess fails to operate successfully, but the larger process can nonetheless proceed.

³ For a treatment of the issues raised in modeling conversion see (Schank and Lehnert, 1979); argumentation is discussed in (Birnbaum, Flowers, and McGuire, 1980).

⁴ We will not try to define 'conceptualization' here. We construe it loosely as a representational structure that is constructed as a consequence of the subject's exposure to the input (given the appropriate background conditions). Specific hypotheses about the properties of these structures will be advanced as we go on.

⁵ A more extended treatment of these sorts of relations must be more sensitive, for instance, to

the distinction between the relations on the rightmost branch, which seem to hold between the events described in narratives, and the others, which hold between the parts of the text used in the description; the set of connections presented here draws heavily on (Hobbs, 1976).

⁶ The sentences in the narrative need not be contiguous in the text for the connections in question to obtain.

⁷ The reader will notice that in this case there are expository connections that relate the various parts of the narrative. In fact all the relations listed under the rightmost 'contiguity' branch come into play in this narrative. Nevertheless, none of these connections occur essentially; they occur only as 'side-effects' of the causal relations that hold between the events in the story. The fact is that we can't construct adequate representations of causal relations without spatial and temporal connections playing a role as well, but this is due to the nature of (our understanding of) causality, not to the general nature of our language processing mechanisms. In one sense, then, the relations listed under the rightmost branch lead a double life. In some instances (for example (8)–(10)) they help set the scene, or provide perspective on the events central to the narrative. In (13) they are more intimately connected with the central story-line.

⁸ By causal connections we mean more than just single strand causal chains – we have to include possible causes and effects, many contributory causes for one effect, etc.

⁹ With hindsight, this position might seem so obvious as to be almost tautological. One could also wonder if there isn't some barely hidden circularity here in the claim that what makes a narrative coherent for a hearer is the computation of its central causal chain? After all, how do we individuate narratives if not in terms of such a dominant causal chain? As it turns out, though, causal connectivity is at least not part of the standard definitions of narrative. It is not mentioned once in the definitions of any of the family of terms associated with 'narrative'. Cf. *narration*: 3. the recitation of a succession of events usually in chronological order and usually with description of the persons involved (*Webster's Third International*).

¹⁰ Here we have in mind rules for dealing with narratives that are in flashback, multiple subjective views of the same events, and so on.

¹¹ In talking of the two sentences as causally connected we mean simply that a significant amount of causal reasoning is required in order to determine the hypothetical chain of consequences that makes the speculation about union coffers appropriate. Everyone knows that such reasoning is required if we are to understand narratives like (16); we are interested in the principles that govern such reasoning and in the mechanisms that make it possible.

¹² To be more precise: the reader doesn't really have to fill in the missing elements. Usually it is enough to determine that suitable events could be constructed. So, for example, if there are many ways Mallory could have used the ladder in (14), the reader needn't commit himself to any one – did he have a friend hold it as he climbed or did he just lean it against the garage and go up? – to construct an adequate conceptualization of the story.

¹³ See (Hayes, 1978), and (Schank, 1973) for some work along these lines.

¹⁴ For a discussion of the psychological evidence see (Abelson, 1980). The linguistic point is made in (Schank and Abelson, 1977), pp. 39–40; cf. (Chastain, 1975).

¹⁵ These possibilities argue for the view that the parsing process must be able to access the hearer's general world knowledge in order to determine the correct meanings of 'ordered' and 'sounded', and to understand that 'the' refers to a type of dish as opposed to a particular baked salmon; for a discussion of these controversial issues see (Schank, Lebowitz, and Birnbaum, 1978).

¹⁶ In this regard see (Quillian, 1968) and (Rieger, 1975).

¹⁷ The conditions of adequacy on a psychological model obviously extend beyond the constraints of accuracy and efficiency mentioned here.

¹⁸ The prospects for such a theory of domain-independent cognitive design are discussed in (Fodor, 1982).

¹⁹ For a comprehensive treatment of scripts see (Schank and Abelson, 1977).

²⁰ This, of course, points to a question we will not take up here: how is it that the appropriate script is triggered at the right time? These issues are discussed in (Cullingford, 1978).

²¹ Similar remarks apply to the problem of pronoun resolution in 'The waiter brought Larry the menu and he ordered the baked salmon'; unless we have information to the contrary – e.g. '... and he ordered the baked salmon for the woman at the next table' – we assume that Larry is doing the ordering; see (Charniak, 1972). Similarly, the reading where the actor does issue commands to his meal might be generated if all else fails – e.g. "Larry sat down at the table, put the napkin on his lap and ordered the baked salmon to go". Our interpretation will depend on how well we know Larry. In this sort of case the script will not be of much help, but the prediction is that to this extent the story will be harder to process; for more on these issues see (Schank and Abelson, 1977).

²² See for instance (Bower, Black, and Turner, 1979), (Gibbs, 1980), and (Galambos, 1981).

²³ This suggests that certain types of newspaper stories might be especially apt for a script-oriented analysis; for discussion of a program that attempts to apply scripts in understanding newspaper stories see (DeJong, 1979).

²⁴ For more on representing the structures of 'plans' and 'goals' see (Schank and Abelson, 1977); for a discussion of a program that processes stories by hypothesizing about the goals and plans of the characters, see (Wilensky, 1978).

²⁵ We have not discussed the fact that many of the causal links in a narrative will also only be of secondary importance since they are not essential to the central story line events. We will not try to specify the notion of a 'central story line' here.

²⁶ See (Birnbaum, Flowers, and McGuire, 1980).

²⁷ We use the term 'memory' euphemistically to cover all the information that the system in question has stored.

²⁸ The foregoing is for the most part conjecture. We are only now in the process of trying to refine these speculations so that we can build empirical models of memory organization. See for example (Schank, 1981), (Schank, 1979), and (Kolodner, 1980).

²⁹ This famous North American folk tale has played a critical role in the development of theories of the schematic representation of narratives. It was first discussed in this context by F. C. Bartlett in (Bartlett, 1932).

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