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Comprehending Consistent and Inconsistent Causal Text Sequences: A Construction-Integration Analysis

Murray Singer
University of Manitoba

Institute of Cognitive Science
University of Colorado
Boulder, Colorado 80309-0344

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University of Manitoba

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Please send proofs to:

Murray Singer
Department of Psychology
University of Manitoba
Winnipeg, Canada R3T 2N2

Abstract

A construction-integration analysis of the comprehension of causal text sequences was performed. According to the validation analysis, the comprehension of both consistent and inconsistent causal sequences requires that tentative bridging inferences be validated with reference to relevant knowledge. Consistent with this proposal, Singer (1993) reported that people needed less time to answer questions about the hypothesized validating facts after consistent and inconsistent sequences than after control, temporal sequences. The construction-integration analysis of these effects focused particularly on a central configuration of causally related propositions. The simulations adopted the following assumptions and parameters: A working memory buffer size of 1 was used. All link strengths had an absolute value of 1. The representations included text base and situation model elements, but no surface elements. The simulation was performed for six randomly selected texts from Singer's (1993) experiments. The results revealed a good qualitative fit between the construction-integration activation of the probe questions and their corresponding answer times: In particular, high activation was associated with fast answer time.

A point of general agreement in the study of text comprehension is that reading leads to the representation of the surface features and idea structure of a message, and of the situation to which the message refers (van Dijk & Kintsch, 1983). In the latter regard, there is growing evidence that the categories of ideas that may contribute to the situation model are essentially unlimited. The situation model may capture the referential, temporal, and spatial relations underlying a text (Graesser & Zwaan, in press). It may also represent the stated or implied motive and goals of a narrative character, the emotional responses of that character, and the reader's perception of the intentions of the writer (Graesser, Singer, & Trabasso, in press).

Few aspects of text meaning have received as much scrutiny as causal structure. One reason for this is that causal relations contribute to the meaning of narratives, expository text, and many other genres (Black, 1985; Trabasso & Sperry, 1985). On-line and memory measures of comprehension have yielded evidence that readers infer the causal structure of text (Black & Bern, 1981; Bloom, Fletcher, van den Broek, Reitz, & Shapiro, 1990; Keenan, Baillet, & Brown, 1984; Magliano, Baggett, Johnson, & Graesser, 1993; Myers, Shinjo, & Duffy, 1987; Potts, Keenan, & Golding, 1988; Singer, 1980; Singer & Ferreira, 1983; Trabasso & Sperry, 1985). A central facet of the extraction of the causal structure of text is the construction of inferential bridges that link the current text idea to what has proceeded. For example, a proper grasp of the sequence, The lightning struck, The hut collapsed requires a bridging inference to the effect that it was the lightning that caused the hut to collapse (Haviland & Clark, 1974; Singer, 1980).

In the present study, the computational analysis of the construction of text causal structure was undertaken. The construction-integration architecture of Kintsch (1988, 1992a, 1993; Kintsch & Welsch, 1991) was used for this purpose. The emphasis was on readers' comprehension of text sequences that are consistent or inconsistent with people's knowledge of causal relations. For example, Laurie placed the ice cubes in the lemonade, The lemonade became cooler is consistent with our general knowledge, whereas Laurie placed the ice cubes in the lemonade, The lemonade became warmer is inconsistent. The comprehension of causal and adversative sequences of this sort is addressed by the inference validation analysis (Singer, 1993, 1994; Singer, Halldorson, Lear, & Andrusiak, 1992). In particular, the validation model examines the implicit reasoning that underlies the construction of bridging inferences.

As discussed earlier, comprehending Laurie placed the ice cubes in the lemonade, The lemonade became cooler requires a causal bridging inference to the effect that the first event caused the second. The validation model adds that, before the tentative bridge between these two sentences is accepted, it must be validated with reference to world knowledge. First, the reader is posited to derive a mediating idea from the text sequence. For the present example, the mediating idea might take a form such as "ice cubes cool lemonade." Second, the mediating idea is evaluated with reference to relevant background knowledge. Because "ice cubes cool lemonade" is consistent with people's knowledge, the inference is validated.

The mediating idea constructed in inference validation need not be consistent with world knowledge. Rather, it is derived from text in a manner that reflects the causality implied by the text structure, rather than text content. As a result, upon reading Laurie placed the ice cubes in the lemonade, The lemonade became warmer, the reader would construct a mediating idea such as "ice cubes warm lemonade." Of course, the comparison of this idea with relevant knowledge would reveal it to be inaccurate. As a result, the reader would reject the causal bridge or recognize the current circumstance as unusual or paradoxical. In principle, validation processing must be able to detect inconsistencies. If it could not, there would be no value in engaging in such processing for consistent sequences.

The Experimental Evidence

Evidence supporting this analysis stems from the experiments of Singer (1993). The present construction-integration analysis addresses the joint results of two experiments that focused on materials such as set (1):

(1) a. Mark poured the bucket of water on the bonfire, so the fire went out. (causal)

b. Mark placed the bucket of water by the bonfire. The fire grew hotter. (temporal)

c. Mark poured the bucket of water on the bonfire, but he fire grew hotter. (inconsistent)

d. Does water extinguish fire?

The subjects read the causal sequence, (1a), the control temporal sequence, (1b), or the inconsistent sequence, (1c). As specified by the validation analysis, reading either (1a) or (1c) should invoke the general knowledge that water extinguishes fire. From the inconsistent sequence, for example, the reader extracts the a mediating idea such as "water feeds fire." The evaluation of this idea with reference to long-term memory accesses the relevant knowledge that water actually quells fire. Temporal sequence (1b), in contrast, does not suggest a causal connection that accesses that knowledge. Therefore, it was predicted that when question (1d) follows these sequences, answer time will be faster in the causal and inconsistent conditions than the temporal conditions.

Experiment 2 of Singer (1993; see also Experiment 1) provided clear support for this hypothesis. Two features of the materials should be noted. First, to have the identical question in each condition, it was impossible to use the same second sentence in all three sequences. Because the crucial new prediction was that the inconsistent answer times would be faster than the temporal answer times, the inconsistent and temporal conditions used the identical second sentences, such as The fire grew hotter. Second, the temporal sequence included no conjunction. This was because there is no conjunction that clearly conveys a temporal relation. Even the neutral "and" and the explicitly temporal "and then" acquire a causal sense when interposed between the sentences of (1b).

The second experiment of interest (Singer, 1993, Experiment 3) differed from the first only in the exclusion from sequences (1a) and (1c) of the appropriate conjunctions, so and but. For example, the inconsistent sequence now stated, Mark poured the bucket of water on the bonfire, The fire grew hotter. This had the distinct impact on the results of eliminating the significant answer time advantage of the inconsistent over the temporal condition. The answer times of Experiments 2 and 3 of Singer (1993) are shown in Table 1.

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Insert Table 1 about here

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The different answer time profiles of the two experiments were explained particularly with reference to the impact of the appropriate conjunction, "but." The use of this adversative is a signal to the reader that the writer acknowledges that the current circumstances are unexpected or unusual. In contrast, the no-conjunction inconsistent sequence, Mark poured the bucket of water on the bonfire, The fire grew hotter may puzzle the readers, and raise some uncertainty as to what they ought to respond to Does water extinguish fire?

A construction-integration analysis was undertaken to achieve a more precise account of the processes underlying these text processes. In general, computer simulation of cognitive processes entails decisions about the details of processing that are not ostensively demanded otherwise. To cite one example, for the construction-integration analysis, it was necessary to specify the characteristics and role of working memory in inference validation in a manner not addressed in previous treatments.

Construction-Integration Analysis of Causal and Adversative Sequences

General Features of the Construction-Integration Model

The construction-integration model provides an architecture for the simulation of language processing phenomena. It has been applied to the recall (Kintsch, 1988) and recognition (Kintsch, Welsch, Schmalhofer, & Zimny, 1990) of text, and to learning from text (Kintsch, 1994). Construction-integration adopts from its predecessor theories (Kintsch & van Dijk, 1978) the principle of the cyclic processing of text. Each cycle of processing consists of a construction phase and an integration phase. During construction, symbolic rules of syntax and semantics construct a "coherence matrix", **C**, of the elements at different levels of text representation. At the text base level, the coherence matrix includes explicit text propositions, their close associates, coherence-preserving inferences, and thematic generalizations of the text (Kintsch, 1988). The symbolic rules that generate the coherence matrix are "weak": for example, they yield both relevant and irrelevant associates. In this regard, a clause that mentions the term "bug" in the spying context will generate associates both about listening devices and insects (cf. Swinney, 1979).

A simple version of the coherence matrix for The hikers were ready to cook, They picked up some wood, is shown in Table 2. Table 2 includes the explicit propositions underlying the sequence, plus one implied proposition, CAUSE(P1,P4). The cells of the matrix show the connection weight between every pair of propositions. Propositions are assumed to have a self-connection with a weight strength of 1. In addition, argument overlap, such as the overlap of HIKERS between P1 and P2, and the embedding of one proposition in another, result in links of weight 1. The only two propositions in this example that are not connected are P2 and P3.

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Insert Table 2 about here

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The symmetry of the matrix is Table 2 is not inevitable. Rather, it rests on the assumption, adopted in the present analysis, that all propositional connections are bidirectional.

In the integration phase of processing, activation is settled in the coherence matrix following connectionist principles of constraint satisfaction. The integration computation involves the postmultiplication of the active part of the coherence matrix (those propositions currently in working memory) by an N x 1 vector of the activations representing the participating elements.

All activations are initially set to one, and after each postmultiplication, are rescaled, based on a value of 1 for the most active element. Iteration continues until the criterion that an average change of .001 in the activation of the vector elements is reached.

One impact of integration is the deactivation of ideas such as the distractor referents of an anaphor and the irrelevant associates of a text idea. Integration produces a final activation vector representing all of the text elements, including those in the surface, text base, and situation model. The activation vector, in turn, modifies the original coherence matrix, **C**, to produce a long-term memory representation of the text, **M**. Formula (1) shows the derivation of the elements of the long-term memory matrix from the coherence matrix (Kintsch & Welsch, 1991):

$$m_{ij} = c_{ij} * a_i * a_j \qquad (1)$$

Analysis of the Comprehension of Causal and Adversative Sequences

Central causal configuration. The goal of the simulation was to provide a parsimonious account of the answer times for the conditions of Experiments 2 and 3 of Singer (1993). The combination of those experiments is described by the crossing of the relations of cause, control, and inconsistent by the presence or absence of appropriate conjunctions. As discussed earlier, answer times for validating ideas were faster in the inconsistent than the control condition when the inconsistency was signaled by the presence of the appropriate conjunction "but," but not in its absence.

Guidelines for the construction-integration simulation of inference validation effects were proposed by Singer (1994). First, as many assumptions and parameters of prior construction-integration analyses as possible were adopted. Second, for the sake of parsimony, the six conditions of the experiments were distinguished by means of the smallest possible number of simulation details. Specific justifications will be offered for those differences. Third, the aim was to create a qualitative simulation of these effects, rather than a quantitative one (e.g., Gillund & Shiffrin, 1984; Kintsch, 1992b). Accordingly, no systematic parameter fitting was conducted. Rather, the concern was whether, on the basis of a defensible set of assumptions and parameters, an ordinal simulation of the effects could be achieved.

The present analysis used a central feature of Singer's (1994) simulations. In particular, a configuration of propositions that captured the crucial causally related ideas and the fact posited to validate them appeared in the representations for all conditions. This feature can be described with reference a causal sequence and a control sequence, shown in set (2).

(2) a. The cave explorer TOOK OUT his pipe. He lit a match. (causal)

b. The cave explorer DROPPED his pipe. He lit a match. (control)

c. Can matches light tobacco?

Sequences (2a) and (2b) represent causal and control sequences, respectively, and question (2c) probes the information posited to validate the causal bridge underlying (2a). Figure 1 shows the central configuration under discussion.

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Insert Figure 1 about here

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Figure 1a represents the causal sequence. It shows seven propositions. Propositions 1 and 2 capture the explicit text ideas, P1 TAKE-OUT(CAVE-EXPLORER, PIPE) and P2 LIGHT(CAVE-EXPLORER, MATCH). Proposition 3 is the abstract bridging proposition that asserts that the first event caused the second, namely P3 CAUSE(P1, P2). Proposition 4, which may be paraphrased as "matches light tobacco," is the mediating idea derived from propositions 1 and 2. Proposition 5 is the fact in long-term memory which supports mediating idea P4. The mediating idea is linked with P1, P2, P3, and P5.

Proposition P100 represents probe question (2c), Can matches light tobacco? This proposition does not participate during the comprehension of sequence (2a). Its presentation initiates another cycle of construction and integration. During construction, P100 is connected with the closely related mediating idea, P4, and the validating idea, P5, in the long-term memory matrix, **M**. In integration, activation flows into the probe from **M.**

Although this arrangement provides all of the information needed to simulate the causal condition, Figure 1a also includes P6, PROVIDE(MATCH,LIGHT). P6 represents an idea in long-term memory that would plausibly validate the contrasting control sequence, (2b), The cave explorer DROPPED his pipe, He lit a match. It is included in the causal condition configuration on the justification that it weakly associated with sequence (2a). However, it does not have a related mediating idea that is analogous to P4.

Figure 1b shows the central configuration for the control sequence, (2b). For this example, P6 PROVIDE(MATCH, LIGHT) has a related mediating idea, P4. In contrast, P5 appears as a weak associate. As in Figure 1a, the probe P100 is still attached to P5 IGNITE(MATCH, TOBACCO), but there is no corresponding mediating idea for it to contact. This reflects the fact that the probe question for both the causal sequence and the control sequence is (2c), Can matches light tobacco? Because probe P100 is connected to an extra idea in Figure 1a, and because that extra idea, P4, is itself richly interconnected in Figure 1a, more activation will accrue to the probe in the causal than the control condition.

Parameters and assumptions of the simulation. To review, Experiments 2 and 3 of Singer (1993) are jointly described by the crossing of the variables of relation and conjunction. Therefore, there are ostensively six experimental conditions to simulate. However, the experimental results and the logic of the design converge on the conclusion that those six conditions collapse to only four meaningfully different ones. First, as explained earlier, the temporal condition did not include a conjunction even in the "appropriate conjunction" experiment. Therefore, the temporal condition was identical in both experiments. The temporal answer times of the two experiments were likewise almost identical (see Table 1).

Second, in many circumstances, the relation between causally related sentences is so plain that the inclusion of causal conjunctions such as "so" and "therefore" is virtually redundant (e.g., Singer, 1986). In this case, the processing underlying the causal conditions with and without the conjunction would be highly similar. This too is borne out by the results shown in Table 1.

Therefore, the simulation analysis was applied to four conditions, which will be called causal, temporal, no-conjunction inconsistent, and conjunction inconsistent. The analyses of these conditions all build on the central configurations of Figure 1. They also share the following features. The working memory buffer size was 1: that is, only the most active proposition of a comprehension cycle was carried over for further processing in the next cycle. Compared with some previous treatments (Kintsch & van Dijk, 1978; Singer, 1982), this is a small working memory parameter. However, the propositions under consideration are complex (van Dijk & Kintsch, 1983). Furthermore, in the event that two or more propositions were tied with the highest activation at the end of a cycle, they were all retained for further processing.

All link strengths had an absolute value of 1. Most link strengths had values of 1, but the representation of the inconsistent sequences included inhibitory links with value -1. A third feature of the analyses was that the representations included no surface elements. This choice has previously been made when surface characteristics of the message have little bearing on the central issues of the simulation (e.g., Kintsch, 1992b; but cf. Kintsch & Welsch, 1991; Singer, 1994). Finally, some other commonalities among the conditions are more conveniently addressed in the context of the detailed analyses.

Detailed treatment of the experimental conditions. To summarize, the 3 (relation) X 2 (conjunction) design of the experiments is proposed to collapse to four conditions: namely, causal, temporal, no-conjunction inconsistent, and conjunction inconsistent. The central causal configuration of propositions, discussed earlier, contributes to the representation in all four conditions. The fine distinctions among the conditions is addressed next.

The discussion will be pursued with reference to sentence set (3), as follows:

(3) a. After five minutes, Rich's shower turned cold. He turned the shower off. (causal)

b. Rich showered with cold water for five minutes. Then he turned the shower up. (temporal)

c. After five minutes, Rich's shower turned cold. He turned the shower up. (no-conjunction inconsistent)

d. After five minutes, Rich's shower turned cold, but he turned the shower up. (conjunction inconsistent)

e. Can cold water be uncomfortable?

Figure 2 shows network representations proposed to capture the essence of the four conditions, graphed with the construction-integration software of Mross and Roberts (1992). The "central configuration" in each condition consists of propositions P3, P5, P6, P7, P8, and P9. These propositions play the roles that were discussed in Figure 1a (although the proposition numbers are different). Briefly, P6 is the abstract bridging proposition that states that P3 BECOME(SHOWER, COLD) caused P5. P7 represents the mediating idea, "cold water is uncomfortable," and P8 is the general knowledge that supports P7. P9 represents general knowledge weakly associated with sequence (3a), and was selected because it happens to validate the temporal sequence. P9 may be paraphrased, "people shower for a limited duration of time."

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Insert Figure 2 about here

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The representation of the causal sequence and probe is shown in Figure 2a. Figure 2a shows numerous propositions in addition to those in the central configuration. P1, P2, and P4 represent other ideas underlying the first sentence of (3a). The propositions numbered with the prefix K represent random long-term memory associates of the relevant facts, P8 and P9. The reason for the inclusion of these propositions will be discussed with reference to the two inconsistent conditions. Finally, P100 represents the probe question.

The representation of the temporal sequences appears in Figure 2b. The only differences between the temporal and causal representations are completely analogous to those already discussed with reference to Figure 1. To review, for the temporal sequence, the alternate mediating idea, P7, is constructed. It is supported by the validating fact, P9. As in the causal condition (Figure 2a), the probe P100 still queries P8. However, it is unrelated to, and therefore not connected to, mediating fact P7.

Figure 2c shows the no-conjunction inconsistent condition. The no-conjunction inconsistent sequence (3c) stated After five minutes, Rich's shower turned cold, He turned the shower up. There is one main difference between this condition and the causal condition. The mediating idea, P7, which is derived from the text and which is insensitive to general knowledge, might be paraphrased as "cold water is pleasant." It is evaluated with reference to the general knowledge, P8, "cold water is unpleasant." Therefore, P7 and P8 are mutually inhibitory, as conveyed by the dashed link. This inhibition, in turn, provides the rationale for the inclusion of the random knowledge associates, K10-15. Without support from general knowledge, familiar validating facts (e.g., P8) would overwhelmed by a completely spurious mediating idea. This is not plausible. Familiar facts in long-term memory are not likely to be overruled by a single contradicting episode.

Finally, the conjunction inconsistent condition is addressed in Figure 2d. Its representation is identical to that of the no-conjunction inconsistent, with one important exception. The conjunction inconsistent representation includes P16 AND(P7, P8). Proposition P16 reflects the presence of the conjunction, "but," in sequence (3d). The predicate of P16 is AND (rather than BUT) because the conjunction of two entities or events is central to the meaning of "but" (Halliday & Hasan, 1976). That is, "but" indicates that two otherwise inconsistent events have occurred together.

The AND component of the meaning of "but" is revealed by the unacceptability of sentences that use both "and" and "but" in combination. This is shown in sentence (4).

*(4) After five minutes, Rich's shower turned cold, and but he turned the shower up.

The AND component of "but" makes the phrase, and but redundant. In contrast, the meaning of the causal conjunction "so" does not include an AND component. As a result, sentence (5) is grammatical (Halliday & Hasan, 1976).

(5) After five minutes, Rich's shower turned cold, and so he turned the shower off.

Construction-integration simulation proceeded similarly for all four conditions. The first sentence of a sequence, represented by propositions P1-P4, was processed during cycle 1. After activation settled, the most active proposition, always P3, was carried over in working memory. The participating propositions of cycle 2 were P3, the propositions representing the second sentence, and all of those propositions invoked by inference validation processes. This included all of the remaining propositions except the probe, P100. The results of each cycle of processing were stored in long-term memory. This means, as discussed earlier, that the resting activation levels of the propositions modified the original coherence matrix, **C**, to yield the long-term memory matrix, **M**.

For the test phase, the probe P100 was connected to its replicas in the long-term memory structure, namely the validating fact, P8, and, depending on the condition, the mediating fact, P7, as well. Activation was settled in this new structure. The simulations were performed for six randomly selected sentence frames of the 21 studied by Singer (1993).

Results and discussion. The evaluation of the simulation is predicated on the assumption that high activation of a test probe promotes fast answer time. The construction-integration program generated a probe activation level with a range of 0 to 1. To facilitate the comparison between answer time and the construction-integration solution, Figure 3 plots the answer times and the inverse of the activations in one graph. The activation scores were the means of the inverse activation across the six texts. It is apparent from Figure 3 that the profile of the curves for the two measures are similar. Therefore, the goal of an ordinal simulation of the answer times was achieved.

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Insert Figure 3 about here

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A deviation from the ideal outcome is that the no-conjunction inconsistent answer time was most similar to that of the temporal condition, whereas the no-conjunction inconsistent inverse activation was most similar to that of the conjunction inconsistent condition. It is possible that varying parameters such as working memory size or link strength might produce an improved fit. Other changes in the representation might be warranted. For example, representing "but" simply with the proposition, AND(Px,Py) is an oversimplification. "But" both conjoins two circumstances, and implies that they are typically inconsistent. A more detailed representation of the concept "but" was employed in other simulations, but this did not alter the pattern of results.

As a result, the present outcome is viewed as constituting a good first approximation to the analysis of inconsistent causal sequences. It is significant that, in many respects, the present simulation adopted the details of the simulation of other inference validation effects. First, Singer (1994) used comparable procedures to compare the present causal and temporal conditions to a condition in which the probed idea had been explicitly stated in the antecedent message. Second, Singer analyzed and compared three reader orienting instructions: a neutral, gist instruction; a summarizing instruction, intended to enhance causal processing; and a proofreading instruction, intended to reduce causal processing. Those analyses yielded satisfactory qualitative simulations of the answer times under examination. Therefore, the features of the present simulation were not devised to address only the four conditions inspected here.

However, it is viewed as an important goal to extend the present analysis of causally consistent and inconsistent sequences. In this regard, it would be instructive to address reading times for the outcome sentence of the sequences (Singer, 1993). However, reading time is one aspect of text processing to which construction-integration has not yet been applied. The task is a complex one. Reading time might be partly determined by the harmony of a text representation (Britton & Gulgoz, 1991; Smolensky, 1986). However, such an analysis would also have to consider the impact on reading time of the number of propositions and arguments in a representation.

The examination of other conditions of inconsistency would likewise further tune the model. Singer's (1993) sequences presented either no conjunction or an appropriate conjunction. It would be instructive to create sequences with inappropriate conjunctions, such as <u>After five minutes, Rich's shower turned cold, BUT he turned the shower off</u>. The enrichment of the relevant data base is likely to guide the refinement of the present analysis.

References

Black, J. B. (1985). An exposition on understanding expository text. In B. Britton & J. Black (Eds.), Understanding expository text . Hillsdale, NJ: Erlbaum.

Black, J. B., & Bern, H. (1981). Causal inference and memory for events in narratives. Journal of Verbal Learning and Verbal Behavior, 20, 267-275.

Bloom, C. P., Fletcher, C. R., van den Broek, P., Reitz, L., & Shapiro, B. P. (1990). An on-line assessment of causal reasoning during comprehension. Memory & Cognition, 18, 65-71.

Britton B. K., & Gulgoz, S. (1991). Using Kintsch's model to improve instructional text: Effects of inference calls on recall and cognitive structures. Journal of Educational Psychology, 83, 329-345.

Graesser, A. C., Singer, M., & Trabasso, T. (in press). Constructing inferences during narrative text comprehension. Psychological Review.

Graesser, A. C., & Zwaan, R. A. (in press). Inference generation and the construction of situation models. In C. Weaver, S. Mannes, and C. Fletcher (Eds.), Discourse comprehension: Strategies and processing revisited. Hillsdale, NJ: Erlbaum.

Gillund, G., & Shiffrin, R. M. (1984). A retrieval model for both recognition and recall. Psychological Review, 91, 1-67.

Halliday, M. A. K., & Hasan, R. (1976). Cohesion in English. London: Longman.

Haviland, S. E., & Clark, H. H. (1974). What's new? Acquiring new information as a process in comprehension. Journal of Verbal Learning and Verbal Behavior, 13, 512-521.

Keenan, J. M., Baillet, S. D., & Brown, P. (1984). The effects of causal cohesion on comprehension and memory. Journal of Verbal Learning and Verbal Behavior, 23, 115-126.

Kintsch, W. (1988). The role of knowledge in discourse comprehension: A construction-integration model. Psychological Review, 95, 163-182.

Kintsch, W. (1992a). A cognitive architecture for comprehension: In H. Pick, P. van den Broek, & D. Knill (Eds.), The study of cognition: Conceptual and methodological issues. Washington, DC: American Psychological Association.

Kintsch, W. (1992b). How readers construct situation models for stories: The role of syntactic cues and causal inferences. In A. Healy, S. Kosslyn, & R. Shiffrin (Eds.), From learning processes to cognitive processes: Essays in honor of William K. Estes. Hillsdale, NJ: Erlbaum.

Kintsch, W. (1994). Text comprehension, memory, and learning. American Psychologist, 49, 294-303.

Kintsch, W., & van Dijk, T. A. (1978). Toward a model of text comprehension and production. Psychological Review, 85, 363-394.

Kintsch, W., & Welsch, D. M. (1991). The construction-integration model: A framework for studying memory for text. In W. Hockley & S. Lewandowsky (Eds.), Relating theory and data: Essays on human memory in honor of Bennet B. Murdock. Hillsdale, NJ: Erlbaum.

Kintsch, W., Welsch, D., Schmalhofer, F., & Zimny, S. (1990). Sentence memory: A theoretical analysis. Journal of Memory and Language, 29, 133-159.

Magliano, J. P., Baggett, W. B., Johnson, B. K., & Graesser, A. C. (1993). The time course of generating causal antecedent and causal consequent inferences. Discourse Processes, 16, 35-53.

Mross, E. & Roberts, J. (1992). The construction integration model: A program and manual. (Technical Report ICS No. 92-14). Boulder, CO: Institute for Cognitive Science, University of Colorado.

Myers, J. L., Shinjo, M., & Duffy, S. A. (1987). Degree of causal relatedness and memory. Journal of Memory and Language, 26, 453-465.

Potts, G. R., Keenan, J. M., & Golding, J. M. (1988). Assessing the occurrence of elaborative inferences: Lexical decision versus naming. Journal of Memory and Language, 27, 399-415.

Singer, M. (1980). The role of case-filling inferences in the coherence of brief passages. Discourse Processes, 3, 185-201.

Singer, M. (1982). Comparing memory for natural and laboratory reading. Journal of Experimental Psychology: General, 111, 331-347.

Singer, M. (1986). Answering yes-no questions about causes. Memory & Cognition, 14, 55-63.

Singer, M. (1993). Causal bridging inferences: Validating consistent and inconsistent sequences. Canadian Journal of Experimental Psychology, 47, 340-359.

Singer, M. (1994). Constructing and validating motive bridging inferences. University of Manitoba, Winnipeg: Manuscript submitted for publication.

Singer, M., & Ferreira, F. (1983). Inferring consequences in story comprehension. Journal of Verbal Learning and Verbal Behavior, 22, 437-448.

Singer, M., Halldorson, M., Lear, J. C., & Andrusiak, P. (1992). Validation of causal bridging inferences. Journal of Memory and Language, 31, 507-524.

Smolensky, P. (1986). Information processing in dynamical systems: Foundations of harmony theory. In D. Rumelhart, J. McClelland, and the PDP Research Group, Parallel distributed processing: Explorations in the microstructure of cognition (Vol. I). Cambridge, MA: Bradford Books.

Swinney, D. A. (1979). Lexical access during sentence comprehension: (Re)consideration of context effects. Journal of Verbal Learning and Verbal Behavior, 18, 645-659.

van Dijk, T. A., & Kintsch, W. (1983). Strategies of discourse comprehension. New York: Academic Press.

Author Notes

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Table 1

Answer Times (in milliseconds; errors rates in parentheses) of Singer (1993) as a Function of Relation

	Relation		
Experiment	Consistent	Temporal	Inconsistent
Experiment 2	2131 (.04)	2331 (.06)	2153 (.06)
Experiment 3	2139 (.05)	2342 (.07)	2274 (.12)

Table 2

Coherence Matrix for Sequence,

"The hikers were ready to cook. They picked up some wood."

	P1	P2	P3	P4
P1 READY(HIKERS,P2)	1	1	1	1
P2 COOK(HIKERS)	1	1	0	1
P3 CAUSE(P1,P4)	1	0	1	1
P4 PICK-UP(HIKERS,WOOD)	1	1	1	1

Figure Captions

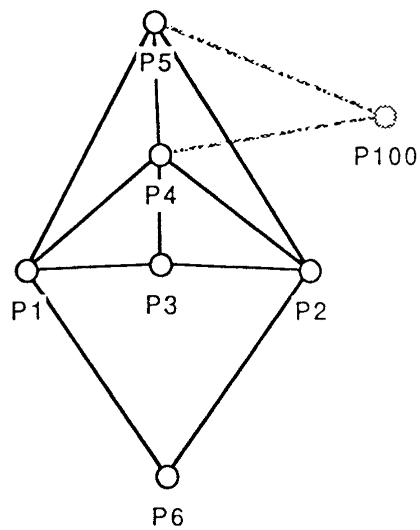
1. Central causally interrelated propositions underlying causal (A) and temporal (B) sequences of sentences.

2. Construction-integration representation of the cave explorer sequence plus test probe in the causal (A), temporal (B), no-conjunction inconsistent (C), and conjunction inconsistent (D) conditions. Propositions P3, P5, P6, P7, P8, and P9 are the antecedent, outcome, CAUSE, mediating, validating, and alternate validating propositions, respectively (see text). Columns 1, 2, and 3 respectively show the proposition label, first cycle of participation, and the element. The test proposition, P100, does not participate in cycles 1 and 2 of comprehension.

(A)

Causal condition: Central configuration

P1 c1 1.0000 TAKE-OUT[CAVE-EXPLORER,PIPE]
P2 c1 1.0000 LIGHT[CAVE-EXPLORER, MATCH)
P3 c1 1.0000 CAUSE[P1,P2]
P4 c1 1.0000 IGNITE[MATCH,TOBACCO]
P5 c1 1.0000 IGNITE[MATCH,TOBACCO]
P6 c1 1.0000 PROVIDE[MATCH,LIGHT]



(B)

Temporal condition: Central configuration

P1 c1 1.0000 DROP[CAVE-EXPLORER,PIPE]
P2 c1 1.0000 LIGHT[CAVE-EXPLORER,
P3 c1 1.0000 CAUSE[P1,P2]
P4 c1 1.0000 PROVIDE[MATCH,LIGHT]
P5 c1 1.0000 IGNITE[MATCH,TOBACCO]
P6 c1 1.0000 PROVIDE[MATCH,LIGHT]

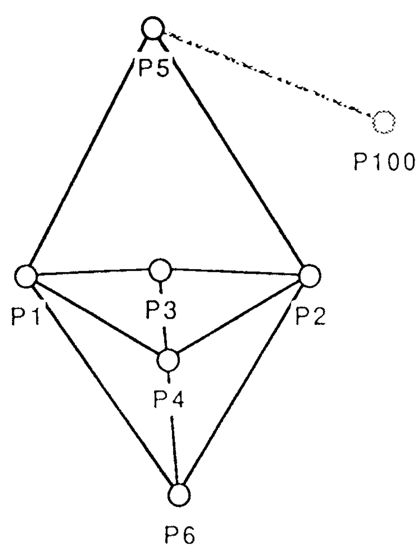
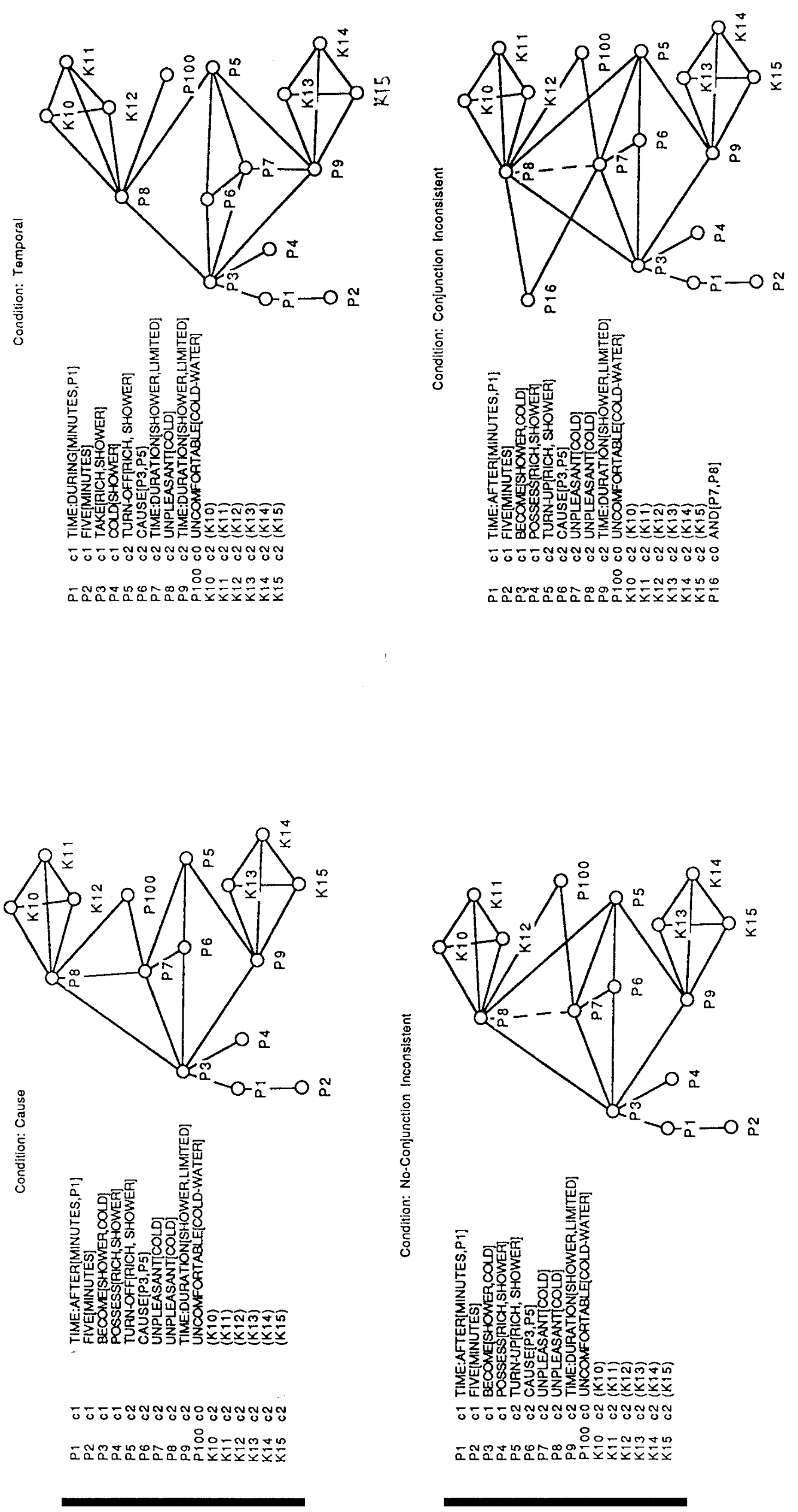
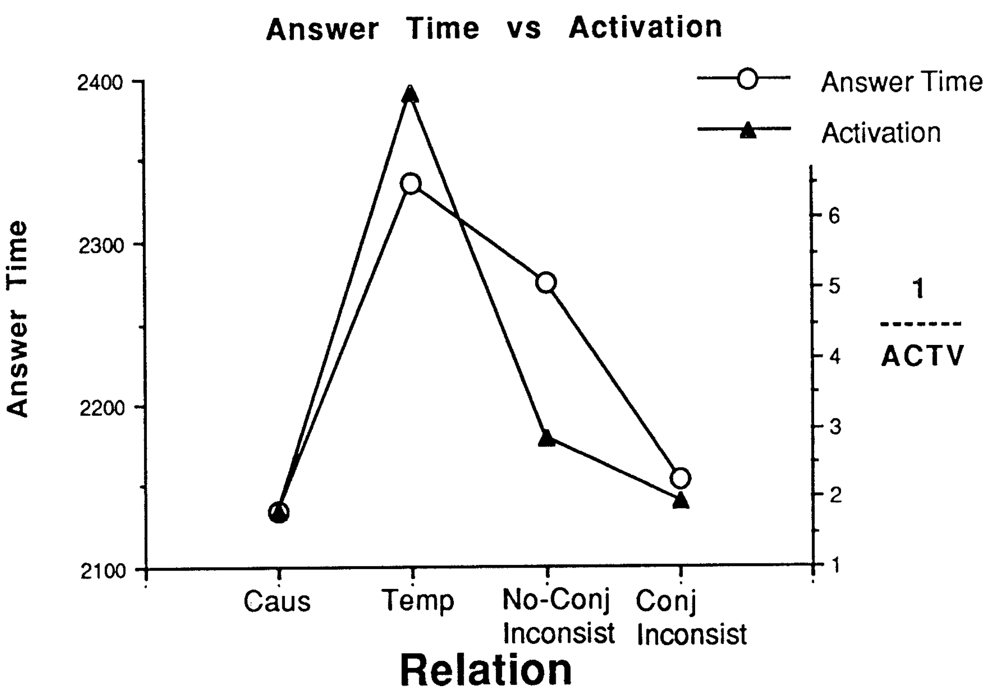


Figure 1

Figure 2


Condition: Cause
P1 c1 TIME:AFTER[MINUTES,P1]
P2 c1 FIVE[MINUTES]
P3 c1 BECOME[SHOWER,COLD]
P4 c1 POSSESS[RICH,SHOWER]
P5 c2 TURN-OFF[RICH, SHOWER]
P6 c2 CAUSE[P3,P5]
P7 c2 UNPLEASANT[COLD]
P8 c2 UNPLEASANT[COLD]
P9 c2 TIME:DURATION[SHOWER,LIMITED]
P100 c0 UNCOMFORTABLE[COLD-WATER]
K10 c2 (K10)
K11 c2 (K11)
K12 c2 (K12)
K13 c2 (K13)
K14 c2 (K14)
K15 c2 (K15)
K10
K11
P8
K12
P100
P7
P3
P6
P5
P1
P4
K13
P9
K14
P2
K15
Condition: No-Conjunction Inconsistent
P1 c1 TIME:AFTER[MINUTES,P1]
P2 c1 FIVE[MINUTES]
P3 c1 BECOME[SHOWER,COLD]
P4 c1 POSSESS[RICH,SHOWER]
P5 c2 TURN-UP[RICH, SHOWER]
P6 c2 CAUSE[P3,P5]
P7 c2 UNPLEASANT[COLD]
P8 c2 UNPLEASANT[COLD]
P9 c2 TIME:DURATION[SHOWER,LIMITED]
P100 c0 UNCOMFORTABLE[COLD-WATER]
K10 c2 (K10)
K11 c2 (K11)
K12 c2 (K12)
K13 c2 (K13)
K14 c2 (K14)
K15 c2 (K15)
Condition: Temporal
P1 c1 TIME:DURING[MINUTES,P1]
P2 c1 FIVE[MINUTES]
P3 c1 TAKE[RICH,SHOWER]
P4 c1 COLD[SHOWER]
P5 c2 TURN-OFF[RICH, SHOWER]
P6 c2 CAUSE[P3,P5]
P7 c2 TIME:DURATION[SHOWER,LIMITED]
P8 c2 UNPLEASANT[COLD]
P9 c2 TIME:DURATION[SHOWER,LIMITED]
P100 c0 UNCOMFORTABLE[COLD-WATER]
K10 c2 (K10)
K11 c2 (K11)
K12 c2 (K12)
K13 c2 (K13)
K14 c2 (K14)
K15 c2 (K15)
Condition: Conjunction Inconsistent
P1 c1 TIME:AFTER[MINUTES,P1]
P2 c1 FIVE[MINUTES]
P3 c1 BECOME[SHOWER,COLD]
P4 c1 POSSESS[RICH,SHOWER]
P5 c2 TURN-UP[RICH, SHOWER]
P6 c2 CAUSE[P3,P5]
P7 c2 UNPLEASANT[COLD]
P8 c2 UNPLEASANT[COLD]
P9 c2 TIME:DURATION[SHOWER,LIMITED]
P100 c0 UNCOMFORTABLE[COLD-WATER]
K10 c2 (K10)
K11 c2 (K11)
K12 c2 (K12)
K13 c2 (K13)
K14 c2 (K14)
K15 c2 (K15)
P16 c0 AND[P7,P8]
P16


Answer Time vs Activation
Answer Time
Activation
2400
2300
2200
2100
Answer Time
6
5
4
3
2
1
1

ACTV
Caus
Temp
No-Conj Inconsist
Conj Inconsist
Relation

Figure 3