DISCOURSE PROCESSES, *33*(2), 105–132


# A Unified Model for Predictive and Bridging Inferences

Franz Schmalhofer
*Institute of Cognitive Science and*
*Department of Psychology*
*University of Osnabrueck*

Mark A. McDaniel
*Department of Psychology*
*University of New Mexico*

Dennis Keefe
*Department of Psychology*
*California State University*

Text materials such as those introduced by McKoon and Ratcliff (1986) have been repeatedly used to shape a theoretical understanding of inference processes. Recent results of Keefe and McDaniel (1993) with these materials were intriguing with respect to the generation and persistence of predictive and bridging inferences. To account for these data, the authors developed a formal model within Kintsch's (1988, 1998) construction–integration theory. Computer simulations confirmed that the model explains the data well. The model's key features are that (a) inferences may be generated and represented at the situational level and thereby differ from explicit statements, which may be encoded in a bottom-up fashion at the surface, propositional, and situational levels and (b) the maintenance of inferences and explicit statements depends on the interconnectivity of the multilevel representation rather than on an independent strength value of an individual knowledge unit. Recent data are described that support these theoretical assumptions. On the basis of this theoretical and empirical work, a unified model is proposed for the generation and persistence of predictive and bridging inferences. The implications of this unified model relative to previous theories are discussed, and a general taxonomy of inference processes is outlined.

Correspondence and requests for reprints should be sent to Franz Schmalhofer, Institute of Cognitive Science, University of Osnabrueck, Kolpingstr. 7, 49069 Osnabrueck, Germany. E-mail: Franz.Schmalhofer@uos.de

One of the central issues in understanding comprehension processes is the dynamics by which inferences are drawn during reading, their maintenance over time, and their interplay with the representation being constructed. Progress on this front has yielded a distinction among several kinds of inferences. One kind of inference is drawn to establish coherence between a just-read clause and a previously read clause; this is typically called a *backward* or *bridging inference* (McKoon & Ratcliff, 1986; Singer & Halldorson, 1996). Another type of inference generates a prediction based on the clause and preexisting knowledge. This type of inference is essentially a knowledge-based elaboration of just-read material—an elaboration that may or may not be needed for establishing text coherence (cf. Seifert, Robertson, & Black, 1985). This kind of assertion or prediction about consequences that are likely items or events in the described situation is typically termed a *predictive* or *forward inference* (Murray, Klin, & Myers, 1993; Whitney, Ritchie, & Crane, 1992). Predictive inferences have therefore been assumed to be encoded as part of a referential situation model rather than as part of the text representation proper (Fincher-Kiefer, 1993).

In the literature there are differences in the experimental paradigms predominantly used to investigate these two nominal types of inferences, differences in the experimental evidence regarding the ubiquity of these inferences, and somewhat different theoretical treatments of these inferences. In this article our goal is to present a unified account of these nominally different inference types by presenting a formal model that we then apply to Keefe and McDaniel's (1993) experiment, which demonstrated the existence of predictive and bridging inferences within the same set of text materials and experimental procedures. After accounting for the main findings of this experiment in terms of a computer simulation model we present a critical experiment for further testing the main assumptions of the model.

Although many researchers have found evidence for the frequent generation of bridging inferences (Bloom, Fletcher, van den Broek, Reitz, & Shapiro, 1990; Klin & Myers, 1993; McKoon & Ratcliff, 1992; Noordman, Vonk, & Kempff, 1992; Singer, Halldorson, Lear, & Andrusiak, 1992), there is much more debate about the spontaneous occurrence of predictive or forward inferences (see Keefe & McDaniel, 1993; Magliano, Baggett, Johnson, & Graesser, 1993; Potts, Keenan, & Golding, 1988). For example, experimental studies have presented sentences such as "The director and the cameraman were preparing to shoot closeups of the actress on the edge of the roof of the 14th story building when suddenly the actress fell." Although not explicitly stated, one can draw the predictive inference that the actress died as a result of the fall.

To test whether readers, in fact, generate such an inference, Potts et al. (1988, Experiments 3 and 4) presented a word probe to readers (e.g., *dead*) subsequent to a sentence that followed the target sentence ("The director was talking to the cameraman and did not see what happened"). They compared the latency to pronounce the probe in this condition with the latency in a condition in which the target sentence could not support the particular inference ("when suddenly the director fell over the camera stand"). They found that there was no reliable difference in latencies. In contrast, when the second sentence ("Her orphaned daughters sued") referred to the information implied by the first sentence, then the latency to pronounce the probe was reliably faster than in the control. On the basis of these data, Potts et al. (1988) concluded that readers, at least with these kinds of texts, construct bridging inferences but do not typically draw predictive inferences.

In a follow-up study, Keefe and McDaniel (1993) replicated these results and found that if the probe was presented immediately after the target sentence, then there was also evidence for the predictive inferences. As in Potts et al.'s (1988) study, if the probe was delayed until after the second sentence was presented, then there was no longer any evidence that the inference had been activated. This is in contrast to the intact priming after the second clause that was observed when the proposition that the actress had died was explicitly stated in the sentence. These data suggest that predictive inferences are drawn but that the dynamics of their construction and representation are not parallel with that of textually presented information. (See Figure 1 for example materials; the sequences of their presentation that were used in the explicit, predictive inferencing, and bridging inferencing conditions; and where priming effects were or were not observed. The sentences of the control condition were identical [Cycle 1], followed by: "when suddenly the director fell over the camera stand" [Cycle 2] and "By the time the camera equipment was set up again it was too dark to continue" [Cycle 3].)

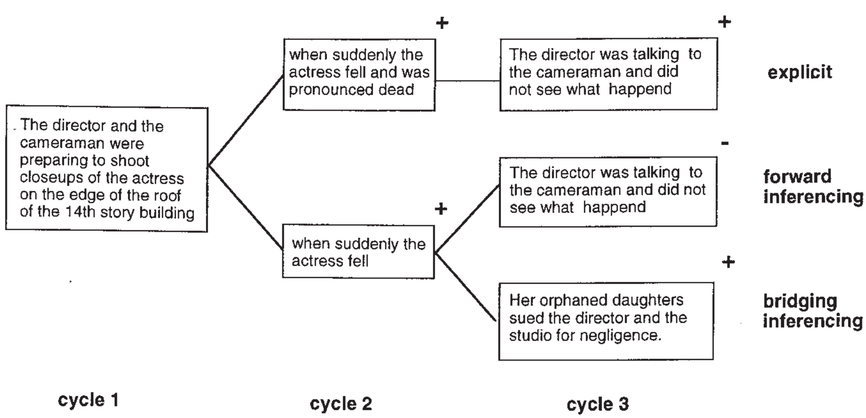


FIGURE 1 Sample texts from the explicit, forward (or predictive), and bridging inferencing conditions used by Keefe and McDaniel (1993) and with some minor differences by McKoon and Ratcliff (1986) and Potts, Keenan, and Golding (1988). With reference to Keefe and McDaniel's Experiment 3, a plus sign (+) indicates the presence of a priming effect, and a negative sign (–) indicates its absence.

A challenge, then, is to understand the implications of the just-mentioned pattern for the processes and representations that underlie predictive inferencing and to examine whether these processes are similar to those involved in bridging inferences (cf. Singer et al., 1992). We apply a prominent theory of text comprehension, namely, Kintsch's (1988, 1998) construction–integration (CI) theory, to help explain these experimental data. In the following section we briefly describe CI theory. We then provide a complete theoretical specification of the generation and maintenance of predictive inferences on the basis of the key ideas of this theory. These specifications are used to conduct computer simulations to examine the extent to which CI theory and its mechanisms can provide a uniform explanation for predictive as well as bridging inferences. The empirical validity of this theoretical account is further supported by a recent experiment in which participants read the same text materials under different reading instructions, either focusing on the wording of the text or the situation implied by the text.

To conduct well-controlled psychological experiments, researchers often use short text materials, such as the ones shown in Table 1. For developing valid theories of inferencing, research with longer stretches of naturalistic texts that are created by writers who genuinely want to convey the presented information to readers is of equal importance (Graesser & Kreuz, 1993, p. 153). Singer and Kintsch (2001) recently demonstrated how CI theory can be applied to longer stretches of text. For the purposes of this article, however, we restrict our discussion to the types of texts shown in Table 1. We certainly would not perform this research with short texts if we did not expect our theoretical results to also generalize to longer stretches of text.

## CI THEORY

CI theory (Kintsch, 1988, 1998; Singer & Kintsch, 2001) posits that text comprehension proceeds by a succession of two kinds of processing phases: construction and integration. During a construction phase, a new text segment (e.g., a clause) is processed, and additional knowledge units that are readily available (Gerrig & McKoon, 1998) or pertinent to the new clause (Graesser, Singer, & Trabasso, 1994) are activated, constructed from the reader's prior knowledge (cf. Graesser & Zwaan, 1995; Singer, 1996), or both. These additional units are produced quite generously, resulting in a quite large collection of possibly redundant and inconsistent units. Each unit or node belongs to one of several representation levels. The nodes of the *surface level* represent the text verbatim in combination with its linguistic structure. The *propositional* nodes represent the meaning and the meaning structure of the text. The *situational* nodes represent the referential state of affairs that is addressed by the text. During the construction phase, these nodes become further connected within their level of representation as well as between adjacent levels of representations (surface to propositional, and propositional to situational). The integration phase determines how well the various nodes fit together to support and supplement each other. These interrelations give rise to a coherent and rather consistent network structure. Nodes that do not fit with this emerging network structure will show low activation values and will therefore become disconnected from the net. The nodes that fit well with the emerging structure, on the other hand, will show high activation values. They are central constituents of the network.

CI theory has been used to explain how several different word meanings are activated, early on, after reading a word (i.e., during the construction phase) and to explain how in the subsequent integration phase the context will determine which of these meanings becomes suppressed (Till, Mross, & Kintsch, 1988). For a word like *mint,* two quite different meanings that are semantically closely related to either money or candy may thus both be generated during the construction phase, and the meaning that is context inappropriate would become disconnected from the network and thus deleted during the integration phase. Because a text is known to be processed in several cycles (Kintsch & van Dijk, 1978), one or several nodes must be carried over to the next processing cycles, if a coherent network is to be achieved as a cognitive representation of the text. The integration phase of the next processing cycle will therefore also include the knowledge units that have been carried over from the previous cycle. If a new propositional unit happens to resonate with some distant text information in long-term memory, then such long-term memory information may also be included in the construction phase (cf. Albrecht & Myers, 1998, pp. 88–89). If some new propositional unit cannot be connected to any of the already-activated information, then a strategic memory search is performed, and an appropriate node is reinstantiated from long-term memory (Miller & Kintsch, 1980).

Any application of a general theory to specific experimental data provokes a number of questions regarding how the general mechanisms of the theory should be applied. In this case the application concerns priming effects in a word pronunciation task. The priming effect serves as an empirical indicator of the mental generation of a corresponding inference or at least as an indicator of mental processes that are usually involved in the generation of an inference. There are several pivotal issues involved: Are tenuous, partial, or minimal inferences generated at the propositional or situational levels? In which ways are inferences different from explicit statements of the text? Which memory parameters of the CI model should be used for predicting priming effects? To address these questions, we built a CI model for the kinds of text materials that were introduced by McKoon and Ratcliff (1986) and more recently used by Potts et al. (1988), Whitney et al. (1992), Keefe and McDaniel (1993), Valencia-Laver and Light (2000), and many others (see Figure 1).

## A MODEL OF INFERENCE GENERATION AND INFERENCE MAINTENANCE

The basic task of applying a computational theory to an experimental data set consists of identifying the theoretical constructs that are most pertinent within the given theory and identifying the aspects of the data that the literature considers most important. In CI theory, multilevel representations, processing cycles with construction and integration phases, and limited memory assumptions yielding carryovers and reinstantiations are generally seen as the pivotal constructs. For the specific experiments, the presence or absence of a priming effect is the central focus. We first provide an explanation of the experimental data using the general constructs of CI theory described earlier. Next we present the computer simulations that verify the sufficiency of our top-level account.

At the top level of the theoretical account, the priming effects in the word pronunciation tasks of Keefe and McDaniel (1993) are predicted by the specific activation values of the critical situational node. Using the situational level as the predictor is most reasonable for these experimental data, because the control conditions of these experiments were designed to minimize word and related priming effects. The control condition contains the same or similar words as the experimental condition, so that word and related priming effects are eliminated when the priming effect is calculated by subtracting the latency of the control condition from the latency of an experimental condition. The effects that are empirically measured are therefore most likely effects that occur at the situational level. Because only one level is used as a predictor, this is also a very parsimonious assumption. After the first clause ("The director and the cameraman were preparing to shoot closeups of the actress on the edge of the roof of the 14th story building") has been processed in the first cycle, the critical clause is presented.

### Second Processing Cycle

For the second clause of the explicit condition it is predicted that the critical situational node will achieve a high activation because this node is strongly interconnected with the propositional level and thus obtains sufficient activation for priming to occur. More specifically, in the explicit condition the second clause reads "when suddenly the actress fell and was pronounced dead." In the construction phase, the surface level, propositional, and situational nodes and the various links interconnecting these nodes are constructed for this clause as usual (cf. Kintsch, Welsch, Schmalhofer, & Zimny, 1990). Because the fact that the actress is dead is explicitly stated, it is represented by verbatim and linguistic nodes (surface level) as well as by propositional nodes and situational nodes. After this construction phase an integration process is performed, yielding various activation values for the different nodes. This integration process produces a high activation for the situational "is dead" node, and a priming effect is thus assumed to occur.

For the second clause of the implicit or inferencing condition the critical situational node will also obtain a high activation value, but for a somewhat different reason. Because the inference is constructed from world knowledge at the situational level, the critical situational node is strongly interconnected, but this time with other nodes at the situational level rather than with the propositional level. More specifically, here the critical clause reads "when suddenly the actress fell." A key feature of CI theory is that elaborations are generously formed during the construction phase. The inference that the actress is dead will thereby be constructed from world knowledge about what can happen when one falls from a great height. The inference is thus represented at the situational level, where it is connected to the "actress falls" node from which it was inferred. Because the actress being dead was not stated in the text (and is not required for establishing a coherent text base), there is no corresponding representation at the propositional or surface levels. Once constructed, the integration process is performed. In this case, the interconnectivity at the situational level will be responsible for yielding a high activation for the situational "is dead" node and the priming effect.

To establish coherence between the second and the third clauses, a restricted number of propositional and situational nodes are held over to be integrated with the information from the third input cycle. Some nodes may also be reinstated from long-term memory. These carryover and reinstantiation processes occur in the same manner in all of the different conditions. It is important that in the explicit condition there are propositional and situational units (stating that the actress is dead) that are carried over, whereas in the implicit condition there is only the respective situational unit. For the third processing cycle one thus obtains the following predictions.

## Third Processing Cycle

In the third processing cycle of the explicit condition there is a high interconnectivity at the propositional level, and the critical situational "is dead" node is well connected with it. Therefore much activation also settles at this situational node, and a priming effect is predicted. More specifically, the third clause reads "The director was talking to the cameraman and did not see what happened." Surface level, propositional, and situational nodes are again constructed for this clause and integrated together with the units that have been held over. The propositional node (about the actress being dead), which is held over from the previous cycle, thereby produces the difference relative to the predictive inference condition, where this node was not constructed and could therefore also not be carried over.

In the predictive inferencing condition the critical situational node is not very well interconnected. Unlike the explicit condition, it is not well interconnected to the propositional level and, unlike the bridging inferencing condition, it is also not well interconnected at the situational level. The absence of a priming effect is therefore predicted for the predictive inferencing condition.

In the bridging inference condition the information that is newly processed connects well at the situational level to the critical situational node. The critical situational node is thus well interconnected at the situational level, and priming is predicted to occur. More specifically, here the third clause reads "Her orphaned daughters sued the director and the studio for negligence." Through elaboration processes and constructions at the situational level, the orphaned daughters and the suing for negligence become related to the "dead actress" node. Consequently a high interconnectivity of the critical node is expected at the situational level, and a priming effect is predicted.

The application of CI theory to this particular set of experimental materials thus shows that, according to the theory, not all empirically observed priming effects are created equal. The priming effects of the explicit conditions are due to the highest interconnectivity occurring at the propositional level, and the priming effects observed for the inferencing conditions (implicit second cycle and bridging inferencing third cycle) are due to the highest interconnectivity occurring at the situational level. The application of CI theory to inferencing thus also yields a differentiating variable, namely, the amount of construction processes at the propositional and situational levels. Because according to the current model the priming effects are not created equal, an experimental manipulation of the strength and extent of propositional and situational constructions should systematically influence the priming effects. Before presenting recent experimental data that test this prediction, we report formal model simulations to verify the sufficiency of our approach.

## COMPUTER SIMULATIONS

We first describe the representational units for the specific texts in the different experimental conditions. We then present how the CI program (Mross & Roberts, 1992) instantiated the three input cycles proposed by our model for the explicit and implicit conditions.[1]

[1] A complete description of these simulation runs may be obtained by writing to Franz Schmalhofer. All of the construction–integration simulations were further rerun and replicated by the Concatex simulation program (van Elst & Schmalhofer, 1998), which is computationally identical to the construction–integration program but has a different kind of user interface. Concatex consists of EXCEL macros and thus uses matrix notation and spreadsheets for representing the network structures, which yield a more readable documentation.

## Representational Specifications

Following the examples developed by Kintsch et al. (1990), we first obtained the surface representations of the text materials: A separate verbatim node was generated for each of the content words, and a linguistic node was generated for each phrase structure of the text. For example, a node was constructed for "the director," another node for "the cameraman," and a third node for the phrase "the director and the cameraman." These nodes were then linked according to the syntactic structures of a sentence, as reported by Kintsch et al. (1990). Figure 2 shows the tree structures that were obtained for the first, second, and third clauses of the different experimental conditions. At this surface level the critical second clauses of the explicit and the implicit conditions differ only by Nodes L12 and S9. Because of the experimental manipulations and the resulting differences in the text materials, these nodes are present in the explicit condition but not in the inferencing conditions. For the various texts that were used by Keefe and McDaniel (1993), the presence or absence of such nodes constitutes the systematic difference between explicit and implicit conditions.

We determined the propositional representations of the specific texts according to the guidelines provided by Bovair and Kieras (1983) and the specific examples of Kintsch et al. (1990). Figure 3 shows the propositions for the three clauses of the explicit and the inferencing conditions. Again, there is only a small difference in

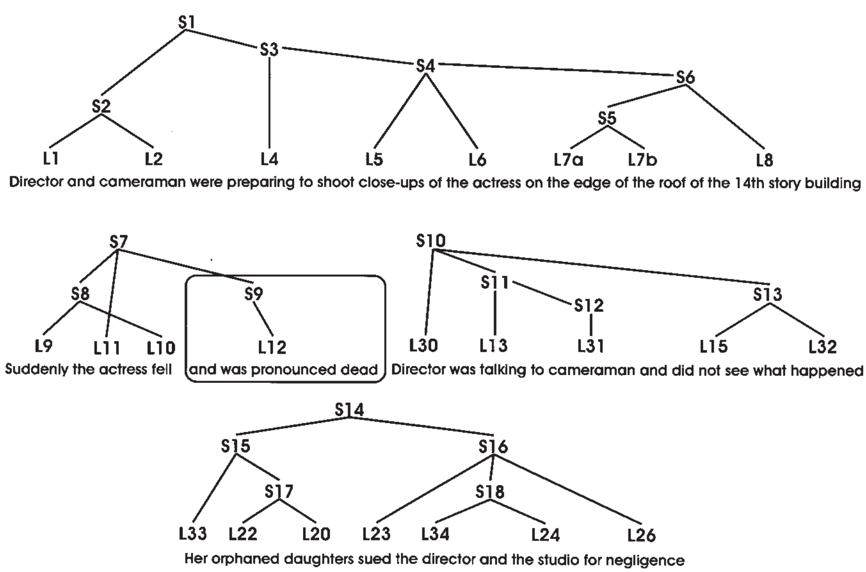


FIGURE 2 Surface representations of the experimental text materials consisting of the linguistic structure (S nodes) and the contents word (L nodes).

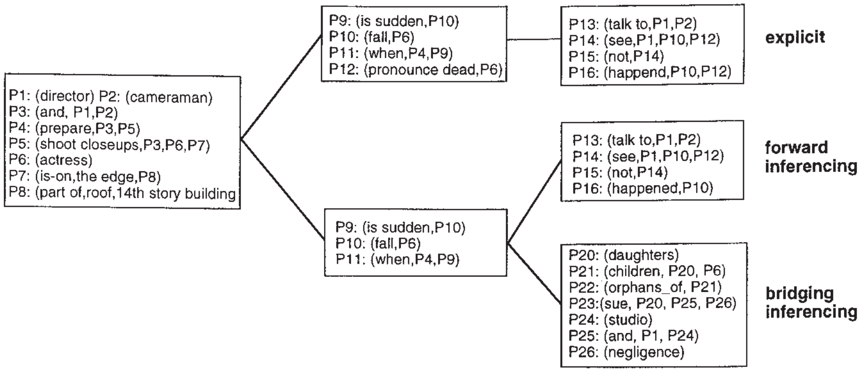


FIGURE 3 Propositional representations of the experimental text materials.

the two representations; namely, the proposition P12, which states that the actress was pronounced dead, is missing in the inferencing condition. For all texts, this is the systematic difference between the explicit and implicit conditions.

The scriptal norms that Galambos (1983) collected provide a good guideline for specifying the situational level for simple narratives like the present texts. A stunt schema was assumed to determine the basic structure of the state of affairs that is referred to by the text (see Figure 4). This stunt schema was represented by a node for the schema header (the node M_s), which has links to the various slots of the schema. By virtue of this schematic structure, the slot fillers, which are also repre-

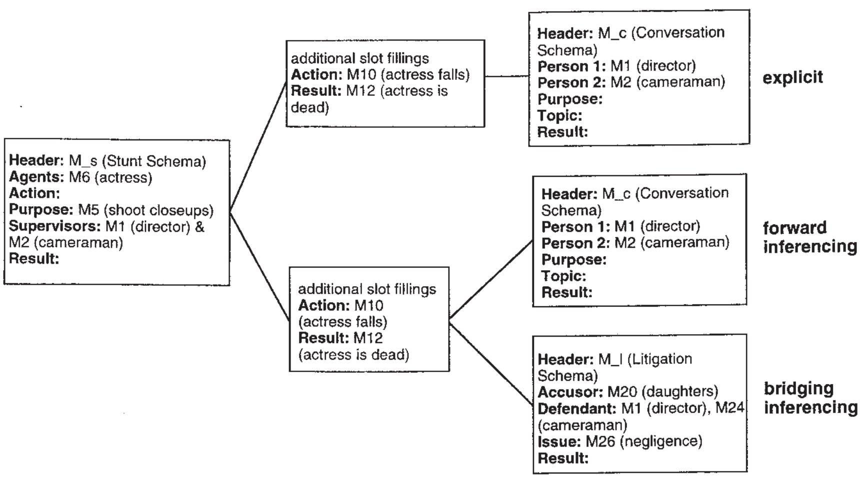


FIGURE 4 Situational representations of the experimental text materials.

sented as nodes, become connected to the schema structure. There is a node for the person performing the stunt (M6), the particular stunt action, the purpose of the stunt, the persons who are in charge or responsible for the stunt, and the result of the stunt action (see Figure 4). For schemas that one might alternatively postulate as the referential situation (e.g., an accident) the simulation yields identical or similar results, as long as this schema is represented by an identical or similar network structure.

## Processing Specifications

Corresponding to the three clauses of the text (see Figure 1), the text was processed by three input cycles (cf. Fletcher & Bloom, 1988; Miller & Kintsch, 1980). Each cycle consisted of a construction phase, in which the surface level, propositional, and situational nodes, and the connecting links, were constructed for the respective text segment. An integration process was then performed with Mross and Roberts's (1992) program. This program simulates the spreading of activation through the network until the activation of each node settles; that is, further processing cycles no longer noticeably change the activation values of a node. The activation values of the various nodes were then recorded. For a rigorous comparison of the model predictions to the experimental data we wanted to eliminate any degrees of freedom that would be due to estimating parameters from the present data set. We therefore used as external parameters of the model the link strengths that Kintsch et al. (1990, p. 143) had already used. We further reduced the variety of values in the parameter set by assuming that the strengths of the situational links would simply be identical to the respective strength values of the propositional and surface levels. The links between adjacent nodes of the situational level thus had a strength value of 3, as did the links at the propositional and surface levels (there were no shortcut links that would have directly connected the nodes that were two links apart). The links from the surface to the propositional level and the links from the propositional to the situational level had a strength value of 4. The link that results from the knowledge-based inference generation (the link between M10 and M12) was similarly assumed to have a strength value of 4. In addition, and again identical to Kintsch et al., each of these nodes is also connected to itself with a strength of 5. These self-connecting links are not shown in Figure 5.

The integration phase of the first processing cycle, which is identical for all conditions, yielded the highest activations for the propositional node P5 and the stunt schema M_s. These two nodes were therefore carried over to the second processing cycle. To establish coherence for the two propositions P11 and P12, the nodes P4, P6, and M6 were furthermore reinstated during the construction phase of the second processing cycle. The first critical difference among the experimental conditions occurs in the second processing cycle. Although in the explicit condition the actress being dead is directly mentioned in the text, in the

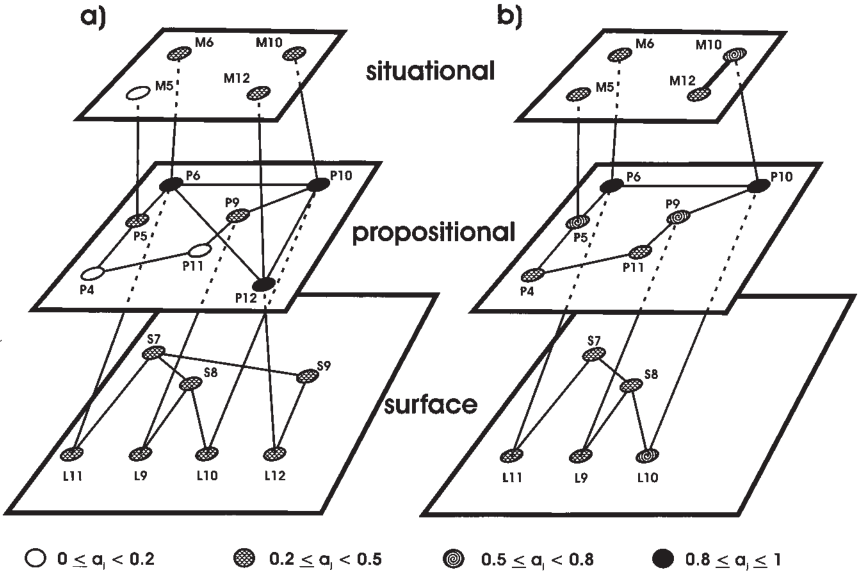


FIGURE 5 Interconnectivity of the network and activation values of the different nodes after the integration process of the second input cycle for (a) the explicit condition and (b) the predictive inferencing condition.

inferencing condition this (potential) fact about the referential situation must be constructed from the world knowledge that is mentally available to the reader. Although in both conditions the (potential) fact of the actress being dead will be formed and cognitively represented at the situational levels, the cognitive processes that construct this representation are necessarily somewhat different. If there are different inputs for the construction process, then the construction process must be adjusted to the differences of the inputs. We therefore explicate these differences in terms of the cognitive processes and the resulting knowledge representations.

In the explicit condition, the actress being dead is directly stated. The respective situation node can therefore be constructed in a bottom-up manner. From the surface forms, propositional nodes are formed that in turn yield the respective situational node (M12), representing the fact that the actress is dead. In the resulting cognitive representation, this path of cognitive processing is reflected by a link between Nodes L12 and P12 and by a link between Nodes P12 and M12.

In the inferencing condition, on the other hand, the circumstances are quite different. The critical fact is not stated in the text. Therefore, there will be no respective representation at the surface level. As a consequence a corresponding propositional node can also not be constructed. The construction of the situational node M12 must thus also proceed differently. It is known that less explicit texts can stimulate more active processing at the situational level (McNamara, Kintsch, Songer, & Kintsch, 1996). This applies not only to texts as a whole but also to individual segments. The situational fact of the actress being dead is therefore actively constructed as the causal consequence of the actress falling (i.e., from Node M10). In the inferencing condition, Node M12 is thus actively generated, and this path of processing is again reflected by a respective link from M10 to M12.

Figure 5 shows the representational consequences of this differential processing. In the explicit condition there are more nodes at the propositional level, which are, in addition, more highly interconnected than in the inferencing condition. This difference is directly due to the nature of the difference between the explicit and the inferencing condition, namely, whether something is explicitly stated or must be inferred. As a consequence, in the integration phase more activation settles at the propositional level in the explicit condition. In the inferencing condition, on the other hand, more activation settles at the situational level. Despite this important difference, the M12 node obtains about the same high level of activation in both conditions, because in the explicit condition it is well connected to the propositional level, and in the implicit condition it is well connected within the situational level. Although for different reasons, a priming effect is thus obtained in both conditions.

In the explicit condition the propositional nodes P6, P10, and P12 are the nodes that obtained the highest activations, and these nodes are therefore carried over to the next processing cycle, together with their situational counterparts (M6, M10, and M12). In the inferencing condition only Nodes P6 and P10 obtained a very high activation, so that here P6, P10, M10, and M12 are carried over as the relevant cluster of nodes.

The construction phases of the third processing cycle are completely identical in the explicit and the forward inferencing conditions. However, there is a difference between the two conditions that is carried over from the previous cycle. As described, this difference lies in the connections among Nodes P10, P12, M10, and M12 and the missing P12 node in the inferencing condition. As a consequence of this difference the explicit condition yields a higher interconnectivity at the propositional level, where Node M12 is well connected to this propositional level. This, in turn, results in a higher activation for the M12 node in the explicit condition than in the inferencing condition. In the inferencing condition the M12 node is somewhat isolated at the situational level and therefore does not obtain much activation.

In the construction phase of the third processing cycle of the bridging inference condition the surface and propositional nodes and links are constructed as usual (see Figures 2 and 3). At the situational level a litigation schema that has slots for accuser, defendant, issue, and result is activated (see Figure 4), and the respective slots are filled. Because the situational “dead actress” node (M12) is closely related to the “orphaned daughters” node (M20) as well as to the issue of the lawsuit

(M26), the construction processes connect Node M12 to Node M20 as well as to Node M26. Thereby a high degree of interconnectivity is obtained at the situational level and around the critical node M12. As it turns out, the integration process therefore yields a high activation for the critical node M12.

The M12 node thus collects a high level of activation, but again for a completely different reason than in the explicit condition. In the explicit condition the high activation of the M12 node was due to the high degree of interconnectivity at the propositional level. In the bridging inference condition, on the other hand, the high activation of the M12 node is due to the interconnectivity at the situational level. It is thus seen that empirically determined priming effects of about equal size may have quite different causes. Depending on the particular network structure, the priming effect may be due to a high interconnectivity at the propositional level or to a high interconnectivity at the situational level.

Table 1 shows a comparison between the exact numerical values we obtained by running the CI simulation program and the empirical priming effects (or inference encoding scores; see Graesser & Zwaan, 1995, p. 126) of the respective experimental conditions from Keefe and McDaniel's (1993) Experiment 3. This comparison shows that there is a close correspondence between the model predictions and the data. Whenever the situational "is dead" node became highly activated by the integration process, a priming effect was also reliably observed in the respective empirical condition. Also, and equally important, in the empirical condition in which there was no significant priming effect (the third input cycle of the forward inference condition), the activation of the critical situational node was also very low. Thus, there is a clear qualitative correspondence between the pattern of the

TABLE 1
A Comparison Between the Model Predictions and the Data of Keefe and McDaniel (1993, Experiment 3) in Terms of Inference Encoding Scores

| | *Model* | | *Data* | |
|---|---|---|---|---|
| *Input Cycle* | *2* | *3* | *2* | *3* |
| Condition | | | | |
| Explicit | 33 | 32 | 30* | 33* |
| Predictive inference | 24 | 6 | 35* | 4 |
| Bridging inference | — | 22 | — | 22* |

*Note.* Following Graesser and Zwaan (1995), we calculated the empirical inference encoding scores by subtracting the mean naming latency for the test word (e.g., dead) in the explicit or inference context from the naming latency of the same test word in the unrelated context. The model predictions consist of the activation values of the situational "is dead" node (M12) that resulted from the integration process. To avoid decimal numbers, we multiplied the activation values of the computer output by 100.

*$p < .05$.

model predictions and the presence or absence of a priming effect in the respective experimental conditions.

In sum, Keefe and McDaniel's (1993) results can be explained well in terms of the general construction and integration mechanisms of CI theory. According to this CI explanation, the persistence of informational units (i.e., inference or explicit statements) is not dependent so much on whether it has been explicitly stated or inferred but is a function of the interconnectivity of the various units at the different levels of representation. In the explicit case the interconnectivity is achieved mostly at the propositional level, whereas in the implicit conditions the interconnectivity is achieved at the situational level. This implication is consistent with recent work on predictive inferences as well, showing that such inferences do remain activated when the foregrounding of the text is consistent with the information inferred (Murray et al., 1993) and may become encoded into long-term memory (Klin, Guzman, & Levine, 1999). When the foregrounding is not consistent with the inferred information, then there is no evidence for continued activation of the inference (Klin & Myers, 1993). Similarly, when the inferred information is no longer in the focus of the discourse, then there is no evidence for a continued activation of the inference (cf. Duffy, 1986; Murray et al., 1993, p. 471).

We evaluated the proposed CI model by comparing its theoretical predictions for the different variations of one of the texts (i.e., the text about the falling actress) with the experimental data. Unlike the model predictions, the experimental data were collected with many different texts. Because the experimental design imposed the important structural manipulations on each one of them, there would appear to be only incidental or irrelevant but no systematic and important variations among the different cover stories. These presumed uniform structural properties in all of the texts are essential for our modeling work, because it would be far too time consuming to perform the reported simulations for all of the different texts.

To reassure ourselves about this uniformity, we looked at all of the stimulus texts and found that some of the experimental materials do have important differences from the text about the falling actress. Whereas the inference from the text about the actress is based on a physical event (i.e., a person falling) and explicates its causal consequence (i.e., the death of the person), there is another group of texts in which the inference is based on some person's needs and motives (e.g., a person being tired) and predicts his or her action (i.e., that the person will sit down on a chair). Some texts of the experimental materials thus invite causal inferences (as the actress text), and the remaining texts invite motivational inferences. Therefore we also performed simulations for one of the texts that invited motivational inferences.

## Motivational Inferences

One of the prototypical texts with a motivational inference is about a tired speaker. The text of the predictive inferencing condition reads as follows: "After standing through the three-hour debate" (Cycle 1), "the tired speaker walked over to his chair" (Cycle 2). "He realized that his valiant effort was probably in vain" (Cycle 3). In the explicit condition, the phrase "and sat down" is added to the second cycle. As in all other texts, the material of the bridging inference condition differs from the predictive inference condition only in the third cycle, which reads "It felt extraordinarily good to get the weight off his tired legs."

We again constructed the different representation levels by using the previously used guidelines. For the first processing cycle we thereby obtained a representation that consisted of 9 nodes at the surface level and 3 nodes at the propositional level. Because the first phrase did not contain sufficient information for explicating a specific situation, there were no knowledge constructions at the situational level. In the second cycle of the inferencing conditions, 10 surface nodes, 3 new propositional nodes, and 3 situational nodes were obtained. The situational nodes were part of a general action schema stating that a person who has specific desires and needs will take an appropriate action to satisfy these needs (cf. Schank & Abelson, 1977). The explicit condition had 2 additional surface nodes and 2 additional propositional nodes, all of which resulted from the statement that the speaker sat down. At the situational level the difference between the explicit and the inference conditions again concerned the interconnectivity. In the explicit condition the situational node of the inference statement was connected to the respective proposition. In the inference condition, on the other hand, the situational node of the inference statement was connected to the situational node that described the motivational precondition, that is, the node from which it was inferentially derived. In the third cycle of the bridging inference condition there were 13 surface nodes, 5 propositional nodes, and 3 situational nodes that filled the result slot of the previously activated schema. In the third cycle of the other two conditions (explicit and predictive inferencing) there were 10 surface nodes, 4 new propositional nodes, and 5 situational nodes that activated a new schema.

By running the simulation program we again obtained simulation results that showed a good qualitative fit to the experimental data (see also Table 1). For the explicit condition, the theoretically derived inference encoding scores were 30 (second cycle) and 19 (third cycle). For the predictive inference condition, the theoretical inference encoding scores were 40 (second cycle) and 0 (third cycle). For the third cycle of the bridging inferencing condition, the respective score was 27. In sum, the modeling of motivational inferences replicated the results we obtained for the causal inferencing condition.

The simulations of the comprehension processes for the two types of texts (causal and motivational) thus yielded the same qualitative pattern of results with somewhat different numerical values. These qualitative fits with two quite different texts corroborate that the model predictions are stable with regard to such incidental variations as the number of words, propositions, or situational units in the various processing cycles of a text. These numbers differed quite widely between the two texts.[2]

## EXPERIMENTAL TESTS

A salient characteristic of our theoretical analyses of the priming data is the assumption of a multilevel representation and the resulting observation from the simulations that the high activation value of the critical situational node (i.e., the M12 node) is sometimes due to a high interconnectivity at the situation level (i.e., in the implicit conditions) and at other times due to a high interconnectivity at the propositional level (i.e., in the explicit conditions). This observation opens up the possibility for a critical experimental test of the current explanation of the observed priming effects. As Schmalhofer and Glavanov (1986) showed, instructions that focus the reader on the formation of a situation model (situation-focused reading) may yield stronger situation representations. Similarly, instructions that focus the reader on the text proper (text-focused reading) may yield stronger (verbatim and propositional) text representations. Situation-focused reading instructions should therefore divert activation to the situation level, and text-focused reading instructions should divert activation to the text levels.

In the terminology of the scenario mapping and focus theory (Sanford & Garrod, 1998) such a manipulation would be said to either stress the implicit focus (situation-focused reading) or the explicit focus (text-focused reading) more strongly. Whenever priming is due to a high interconnectivity at the situational level, the priming effect should consequently get stronger when a reader focuses on the construction of the situation model during reading as opposed to focusing on the text. More specifically, in the third processing cycle of the predictive inferencing condition situation-focused reading instructions would yield more elaborations at the situational level, which in turn yields the provocative prediction from the model that, even at this late time of testing, priming should now occur in the predictive inferencing condition.

Because in the bridging inferencing condition the priming effect is similarly due to the interconnectivity at the situational level, situation-focused reading instructions may similarly increase the priming effect in the bridging inferencing

[2]In text research such variations in materials often motivate statistical analyses with texts (rather than participants) as an incidental random variable. For the different planned pairwise comparisons, Keefe and McDaniel (1993) also performed such analyses. We may therefore additionally confirm the observed qualitative fits between the model and the data by calculating the respective statistical tests for the simulation outputs. Although for the simulation data there are only a few observations for each statistical test, the statistical tests on the simulation outputs replicated the results from the planned pairwise comparisons Keefe and McDaniel (1993, p. 458) reported.

condition compared to text-focused reading instructions. On the other hand, whenever priming is due to a high interconnectivity at the propositional level, as in the explicit condition, the priming effect should get stronger when a reader focuses on the wording of the text during reading as opposed to focusing on the construction of the situation model.

We (McDaniel, Schmalhofer, & Keefe, 2001) tested the foregoing predictions. We implemented two different reading instructions in which the participants either had to focus on the text proper (text-focused reading) or the situation described by the text (situation-focused reading). Our model predicts that when the reading focus is on the situational level, a priming effect will occur in the predictive inferencing condition in a context in which that condition previously has not shown this effect. More specifically, a priming effect is expected in the situation-focused reading condition after the third processing cycle of the predictive inferencing condition. This is because the situation-focused reading instruction yields a more elaborate situational elaboration so that previously unconnected situational nodes are now connected. In terms of the computer simulation, the M_c nodes (see Figure 4) thus become connected to the M10 and the M12 nodes (for the predictive as well as the explicit conditions of the situation-focused reading condition). Because this is an elaboration or inference, the node strength 4 is again used. In text-focused reading no such elaborations are stimulated, and the networks remain as they have been described.

The change of processing effort toward verbatim and propositional representations (in the text-focused reading instructions) or toward the situation level (in the situation-focused reading instructions) was reflected by modifying the self-referential links at the respective levels. For text-focused reading the values of the three levels were 6 (verbatim), 6 (propositional), and 4 (situational level). For situation-focused reading the respective values were 5 (verbatim), 5 (propositional), and 6 (situational level). These strength values agree quite well with the computer simulation of the differences between text- and situation-focused reading instructions in Schmalhofer and Glavanov's (1986) experiment (Experiment 3), which Schmalhofer (1998, pp. 150–158) recently performed. As in this previous computer simulation, the strength values were again set under the algorithm in which reading with a particular focus (text or situation) produces higher strength values at the respective level of representation and possibly lower strength values at the other levels. Recall that a strength value of 5 was used for all three levels in the modeling of Keefe and McDaniel's (1993) experiment in which no specific reading focus was instructed. For the critical levels the selected values were thus appropriately higher than the value of 5, which was used for reading without a particular reading focus. Table 2 shows the numerical predictions of the model for McDaniel et al.'s (2001) experiment along with the priming results from that experiment.

As can be seen in the table, the entire pattern of results converges with that anticipated by the model. The model correctly predicted significant priming for

TABLE 2
A Comparison Between the Model Predictions and McDaniel, Schmalhofer, and Keefe (2001) Data for Text- and Situation-Focused Reading for the Third Processing Cycle in Terms of Inference Encoding Scores

| | *Model* | | *Data* | |
|---|---|---|---|---|
| *Reading Focus* | *Text* | *Situation* | *Text* | *Situation* |
| Condition | | | | |
| Explicit | 23 | 63 | 59* | 43* |
| Predictive inference | 5 | 61 | 14 | 45* |
| Bridging inference | 21 | 41 | 33* | 58* |

*Note.* For a detailed explanation of the presented scores, see Table 1.
*$p < .05$.

the predictive inference condition (even when the probe was delayed until after a second sentence), provided that the situational representation continued to receive activation. The model correctly predicted that priming in the predictive condition would not be obtained (for the probe after the second sentence) when the situational representation was not a specific focus during reading (i.e., in the text-focused condition). This pattern of results converges with the model's premise that predictive inferences are represented at the level of the situational representation.

Furthermore, our model anticipated an increase in priming (for the probe) for the situation-focused reading condition relative to the text-focused reading condition for the bridging inference condition. Because the model views bridging inferences as being constructed and represented in the same manner as predictive inferences, the situational representation of the inference should profit from activation to the situational level (i.e., situation-focused reading). The numeric priming patterns we observed in our (McDaniel et al., 2001) experiment are as predicted.

The predictions emanating from our model are based on details of the representation of the inference and its state of activation, aspects that are not captured in other frameworks. Without such assumptions, existing frameworks of predictive inferencing would not necessarily predict our (McDaniel et al., 2001) finding that predictive inferences remain active after presentation of the second sentence under conditions in which the situational representation receives focal attention but do not remain active otherwise (with materials of the type used here). Some frameworks posit that, once inferences are drawn, they are represented at a propositional level (Keenan & Kintsch, 1973). Given that the predictive inferences appear to be drawn for the present materials (Keefe & McDaniel, 1993), the implication is that activation of the inference should persist (to the extent that activation of the explicitly presented information persists). This expectation clearly is not consistent with both the present results and past findings.

Other frameworks suggest that predictive inferences are minimally drawn and are only marginally represented (or activated) unless subsequent text reinforces the inference in which it may become fully represented (McKoon & Ratcliff, 1992; Singer et al., 1992). In a post hoc fashion, these frameworks might account for our findings by suggesting that predictive inferences are fully drawn under conditions in which the reader is focusing primarily on the situational information conveyed by the text and are accordingly maintained subsequent to the target (first) sentence. Note that this account still diverges from our model. As developed earlier in this article, in our model the inference is typically drawn, even under conditions that do not specifically focus the reader on situational aspects of the text. Because the inference is represented at the situational level, it will be reflected in the knowledge net, but it will not necessarily remain active unless further text reinforces the inference or unless the reader for whatever reason focuses on the situational level. The two foregoing accounts could possibly be distinguished. For instance, the minimalist view might expect that, under standard reading conditions, when the inference is not reinforced by subsequent text, there would be a very minimal trace, if any, of the drawn inference. In contrast, our model holds that under standard reading conditions the inference is still fully represented at the situational level and will therefore become part of the long-term memory representation, as Klin, Murray, Levine, and Guzman (1999) recently found. If later text inputs afforded a boost in activation for that situational node, then the inference would be evidenced. Delayed recognition probe results from McKoon and Ratcliff's (1986) Experiment 4 are consistent with this expectation. A boost in activation may also occur when some newly available information resonates with a situational node or a cluster of situational nodes (cf. Albrecht & Myers, 1998; Myers & O'Brien, 1998), or when a reader actively seeks to link some information to a node that is part of a causal structure (cf. Noordman & Vonk, 1998; van den Broek, 1990).

## GENERAL DISCUSSION

In the early models on inferencing in text comprehension it has been assumed that once an inference is drawn its representation persists in the same way as the encoding of an explicit statement. As Kintsch (1974) assumed

> if there were some propositions in the original text base that were not expressed explicitly in the text itself, the reader will infer these propositions and store them in memory in the same way as other propositions that were presented explicitly in the text. (p. 54; cf. Keenan & Kintsch, 1973; Suh & Trabasso, 1993)

This assumption has been based on an atomistic view of text representation, whereby the different meaning units (i.e., propositions) are identical for inferred and explicitly presented information (e.g., Kintsch & van Dijk, 1978; McKoon & Ratcliff, 1992). Moreover, the links between these propositions mostly represent the coherence of the text without influencing the representational strengths of the propositions themselves. The influence of the links on the memory representation is only indirect, in that the links may determine the propositions that stay in working memory and are thus better remembered as a consequence of repeated rehearsal (cf. Fletcher, 1986; Miller & Kintsch, 1980).

The extensive experimental research of the last 15 years has produced an increasingly more differentiated picture. In the experimental research, several nominal distinctions of inferences have been introduced (cf. Graesser, Singer, & Trabasso, 1994, p. 375; Seifert et al., 1985; Singer, 1994) and assessed by online as well as memory measures. This research has led to a fundamental distinction between two kinds of inferences: predictive and bridging (McKoon & Ratcliff, 1986, 1992; Potts et al., 1988; Singer & Halldorson, 1996). The conventional thinking has been that a bridging inference is generated at a point in which some sort of incoherence (e.g., referential, McKoon & Ratcliff, 1980; or causal, motivational, Singer, 1996; and similar types of higher level relations, Graesser et al., 1994) has been found between the currently processed clause and preceding clauses. Because texts are coherent structures that are not always reflected in the surface forms, bridging (or backward) inferences were assumed to be a necessary part of text comprehension (Kintsch & van Dijk, 1978). A predictive (or forward) inference, on the other hand, was assumed to be based on world knowledge that is used to elaborate some text information, for example, to predict some future event, a motivational state of an agent, and so on. Predictive inferences were therefore seen to be optional, occurring only when such information is automatically available or under special processing goals (McKoon & Ratcliff, 1992).

In the theoretical research of the last 25 years the early theories of text representation (Kintsch, 1974) have evolved into more complete theories about different kinds of cognitive representations and processes. In particular, one now distinguishes among different levels of meaning representations (Fletcher, 1994; Graesser, Millis, & Zwaan, 1997; Perrig & Kintsch, 1985; Schmalhofer & Glavanov, 1986; van Dijk & Kintsch, 1983). The aforementioned terminology of nominally different types of inferences should therefore not remain in isolation from these newer theories that clearly distinguish between text representation proper and a referential situation model and sequences of processing cycles (Graesser et al., 1994; Kintsch, 1998).[3]

[3]By defining different inference types on the basis of psychological process theories (e.g., CI theory), nominal distinctions of inferences that are currently used in experimental research can be developed into a more theoretically founded taxonomy of inference processes. Guthke (1991) and Kintsch (1993, 1998) similarly suggested a more process-oriented classification of inferences in text comprehension.

In the computer modeling of inference processes, however, the distinction of text and situation representations has not yet received much attention. In Kintsch's (1988) original modeling work with CI theory, only the propositional level was used to illustrate the theory's explanation for topological inferences. Specifically, to account for Till et al.'s (1988) inferencing data, Kintsch (1988) restricted his analysis to the propositional net and added a cause–effect node to this level to represent the inference. Singer and Halldorson (1996) similarly used just the propositional representation for predicting a speedup of processing times due to the construction of appropriate motivational inferences. The important question according to the foregoing accounts thus concerns the levels of representation and the point in time at which inference units are generated.

To address this question we considered several experimental data sets that systematically manipulated the text materials so that the inference conditions coincided with the classical nominal distinction between predictive (forward) and bridging (backward) inferences. By using the assumptions of the CI framework (Kintsch, 1988, 1998) we were able to theoretically unravel the underlying components of predictive and bridging inferences. In doing so we found that, at least for these materials, both types of inference conditions could be explained within one unified account. One mechanism (that depends on world knowledge) constructs the inferences in both situations, and an integration component determines its persistence. Similar to the model inferences Lea (1995) investigated, it was assumed that these inferences are generated at the situational level and are held in working memory as a part of the reader's situation model (cf. Fincher-Kiefer, 1996). In this view, the difference between a predictive and bridging inference is not the time at which they are generated or the mechanism by which they are constructed. Instead, bridging inferences may well originate as predictive inferences, but bridging inferences are later substantiated by a subsequent clause.

Other kinds of text materials may clearly afford different generation processes for bridging or backward inferences. For example, research conducted by Myers, O'Brien, and their colleagues (e.g., Myers, O'Brien, Albrecht, & Mason, 1994) showed that information in long-term memory, or possibly in long-term working memory (Ericsson & Kintsch, 1995), may resonate with some newly processed text information (Albrecht & Myers, 1998; Myers & O'Brien, 1998) and subsequently produce a referential or bridging inference in a mental model (Albrecht & O'Brien, 1993). Such experimental evidence indicates that global information required for causal bridging inferences is activated even when there is no coherence break in the currently processed text segment (Cook, Halleran, & O'Brien, 1998). Because our experimental text materials are much shorter than the materials Myers, O'Brien, and their colleagues studied, such long-range resonance processes could not play any role in our theoretical and experimental research. However, our model may well be extended to longer texts in which resonance processes may occur when bridging inferences are constructed to distant text information (Albrecht & Myers, 1998).

Another mechanism that generates causal inferences has been described by the validation model (Singer et al., 1992). Singer (1996) also successfully modeled his proposed mechanism within the framework of Kintsch's CI theory. His CI analysis included text base as well as situation model elements and focused on causally related propositions and thus on the propositional level. According to Singer (1996), a causal inference may require a reader to work backward from some newly read information to previously presented ideas. Because the causal inferences proposed by Singer are generated from the second sentence backward, they are best referred to as *backward inferences*.

For instance, when reading the second sentence of the two-sentence text "After five minutes, Rich's shower turned cold. He turned the shower off," it may be noticed that the two sentences do not causally connect (Singer, 1996, p. 2). Therefore, the required link with the informational contents of "cold water is uncomfortable" may be generated from the two sentences by abductive reasoning as well as for a respective inconsistent causal sequence such as "… He turned the shower up." This tentative inference is subsequently validated against general knowledge.

Similarly, when reading "Chlorine compounds do not react with other substances. They make good propellants" (cf. Noordman et al., 1992), abductive reasoning may produce the tentative mediating idea "Propellants must not react with other substances," which may then subsequently be validated with reference to the relevant domain knowledge. Singer (1996) thus proposed a knowledge domain independent idea generation process that relies on general heuristics that are triggered by a causal incoherence. Domain knowledge is used only for the validation of the idea during the subsequent knowledge integration phase.

Singer's (1996) backward inference generation process is thus substantially different from the knowledge-based inference generation processes that we have described in our unified model of inferences. Therefore, within the framework of CI theory, the two mechanisms supplement each other quite well. As Noordman et al. (1992, p. 588) conjectured, "the reader's knowledge is an important factor in controlling the inference process." Because abductive reasoning does not require domain-specific knowledge, it may be predicted that the backward inferences Singer proposed occur more frequently in readers who are domain novices and that the bridging inferences of our unified model can be observed in readers who are more expert in the specific content domain of the text. For events such as an actress falling from a high building every person possesses the relevant domain knowledge and must thus technically be classified as an expert. However, not everybody is an expert on natural science or information technology (Noordman et al., 1992; Schmalhofer, 1998, Experiment 8).

According to Kintsch's (1993, 1998, p. 189) classification process, Singer's causal inferences may be described as memory retrieval in search for bridging knowledge. The inference generation of the proposed unified model, on the other hand, originates when reading the first sentence and is grounded in knowledge-based elaborations of the presented information. These elaborations are later bridged to other domain knowledge that is constructed from a subsequent sentence. These inferences are therefore best termed *bridging inferences*. According to the aforementioned classification scheme, these inferences would be described as associative elaborations of presented information.

With reference to the levels-of-representation assumption we may similarly distinguish between predictive and forward inferences, which have so far been used synonymously in the literature. Whereas predictive inferences are about the state of affairs described by the text and represented in the situation model, forward inferences are about what an author will say next in the text. Unlike predictive inferences, forward inferences should therefore be represented as part of the text base. Forward inferences may thus behave quite differently from predictive inferences. Furthermore, in our account, inferences and explicit statements differ with respect to the levels at which they exist in the cognitive representation (van Dijk & Kintsch, 1983). Predictive and bridging inferences exist only at the situational level; forward and backward inferences are grounded at the propositional level; and explicit statements may exist at three levels: surface, propositional, and situational. Similar to other views, the account assumes that, once drawn, the inference is part of the representation. The distinction between forward and predictive inferences as well as the distinction between backward and bridging inferences are consonant with the distinction between the explicit focus and the implicit focus in Sanford and Garrod's (1998) scenario-mapping model. In the scenario-mapping model the explicit focus tracks the currently relevant discourse entities, and the implicit focus represents the currently relevant situations (actions, events, etc.), which are termed *scenarios*. There is also empirical evidence that text and situation representations differ with respect to the brain hemisphere in which they are predominately processed and stored (cf. Long & Baynes, in press).

According to our view, though, the critical representational aspect for influencing behavior such as priming, memory, and so on, is the interconnectivity of the nodes at and between the different levels. If the interconnectivity of the critical node is high because of the integration of related information, then the representation of the inference will maintain a high level of activation (as in the bridging condition). If the interconnectivity is low, then the representation of the inference will be only slightly activated (as in the neutral and text- but not situation-focused reading conditions of the predictive text after the third clause has been read).

Although the interconnectivity among the multiple levels is a fundamental aspect of CI theory, some previous models based on this theory have simulated only a single level of the network to derive experimental predictions. Our work has shown that the presence or absence of a few nodes at the propositional and surface levels can have a significant influence on the activation values of the nodes at a third level (i.e., the situational level). A key general point here is that the level that is presumably functionally related to the behavior of interest is substantially influenced by the nodes from the other levels. Because this is one of the core theoretical assumptions of CI theory (Kintsch, 1998) and, as we have shown, this assumption significantly affects the dynamic settling of the network, the multilevel assumption is quite important and should be instantiated when formal CI models are developed to explain comprehension and inference processes.

## ACKNOWLEDGMENTS

Portions of the theoretical model were presented at the 1996 Winter Text Conference in Jackson Hole, Wyoming and at the “Inference During Reading” conference in Montpellier, France, March 1996. This research was partially funded by Deutsche Forschungsgemeinschaft Grant Schm 648–11 to Franz Schmalhofer. We thank Ludger van Elst for his assistance in running the computer simulations. We are grateful to Walter Kintsch and Murray Singer for their insightful comments on earlier versions of this article. We also acknowledge the advice from Art Glenberg, Art Graesser, Walter Kintsch, and the anonymous reviewers who helped us to improve this article.

## REFERENCES

Albrecht, J. E., & Myers, J. L. (1998). Accessing distant text information during reading: Effects of contextual cues. *Discourse Processes, 26,* 87–107.

Albrecht, J. E., & O’Brien, E. J. (1993). Updating a mental model: Maintaining both local and global coherence. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 19,* 1061–1070.

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

Bovair, S., & Kieras, D. E. (1983). A guide to propositional analysis for research on technical prose. In B. K. Britton & J. B. Black (Eds.), *Understanding expository prose* (pp. 315–362). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Cook, A. E., Halleran, J. G., & O’Brien, E. J. (1998) What is really available during reading? A memory-based view of text processing. *Discourse Processes, 26,* 109–129.

Duffy, S. A. (1986). Role of expectations in sentence integration. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 12,* 208–219.

Ericsson, K. A., & Kintsch, W. (1995). Long-term working memory. *Psychological Review, 102,* 211–245.

Fincher-Kiefer, R. (1993). The role of predictive inferences in situation model construction. *Discourse Processes, 16,* 99–124.

Fincher-Kiefer, R. (1996). Encoding differences between bridging and predictive inferences. *Discourse Processes, 22,* 225–246.

Fletcher, C. R. (1986). Strategies for the allocation of short-term memory during comprehension. *Journal of Memory and Language, 25,* 43–58.

Fletcher, C. R. (1994). Levels of representation in memory for discourse. In M. A. Gernsbacher (Ed.), *Handbook of psycholinguistics* (pp. 589–607). San Diego, CA: Academic.

Fletcher, C. R., & Bloom, C. P. (1988). Causal reasoning in the comprehension of simple narrative texts. *Journal of Memory and Language, 27,* 235–244.

Galambos, J. A. (1983). Normative studies of six characteristics of our knowledge about common activities. *Behavior Research Methods and Instrumentation, 15,* 327–340.

Gerrig, R. J., & McKoon, G. (1998). The readiness is all: The functionality of memory-based text processing. *Discourse Processes, 26,* 67–86.

Graesser, A. C., & Kreuz, R. J. (1993). A theory of inference generation during text comprehension. *Discourse Processes, 16,* 145–160.

Graesser, A. C., Millis, K. K., & Zwaan, R. A. (1997). Discourse comprehension. *Annual Review of Psychology, 48,* 163–189.

Graesser, A. C., Singer, M., & Trabasso, T. (1994). Constructing inferences during narrative text comprehension. *Psychological Review, 101,* 371–395.

Graesser, A. C., & Zwaan, R. A. (1995). Inference generation and the construction of situation models. In C. A. Weaver III, S. Mannes, & C. R. Fletcher (Eds.), *Discourse comprehension: Essays in honor of Walter Kintsch* (pp. 117–139). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Guthke, T. (1991). *Psychologische Untersuchungen zu Inferenzen beim Satz- und Textverstehen* [Psychological investigations about inferences in the comprehension of sentences and texts]. Unpublished doctoral dissertation, Humboldt Universitaet Berlin, Berlin, Germany.

Keefe, D. E., & McDaniel, M. A. (1993). The time course and durability of predictive inferences. *Journal of Memory and Language, 32,* 446–463.

Keenan, J., & Kintsch, W. (1973). Reading rate and retention as a function of the number of propositions in the base structure of sentences. *Cognitive Psychology, 5,* 257–274.

Kintsch, W. (1974). *The representation of meaning in memory.* Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

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

Kintsch, W. (1993). Information accretion and reduction in text processing: Inferences. *Discourse Processes, 16,* 193–202.

Kintsch, W. (1998). *Comprehension: A paradigm for cognition*. New York: Cambridge University Press.

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., Schmalhofer, F., & Zimny, S. (1990). Sentence memory: A theoretical analysis. *Journal of Memory and Language, 29,* 133–159.

Klin, C. M., Guzman, A. E., & Levine, W. H. (1999). Prevalence and persistence of predictive inferences. *Journal of Memory and Language, 40,* 593–604.

Klin, C. M., Murray, J. D., Levine, W. H., & Guzman, A. E. (1999). Forward inferences: From activation to long-term memory. *Discourse Processes, 27,* 241–260.

Klin, C. M., & Myers, J. L. (1993). Reinstatement of causal information during reading. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 19,* 554–560.

Lea, R. B. (1995). On-line evidence for elaborative logical inferences in text. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21,* 1469–1482.

Long, D. L., & Baynes, K. (in press). Discourse representation in two cerebral hemispheres. *Journal of Cognitive Neuroscience*.

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

McDaniel, M. A., Schmalhofer, F., & Keefe, D. (2001). What is minimal about predictive inferences? *Psychonomic Bulletin & Review, 8,* 840–846.

McKoon, G., & Ratcliff, R. (1980). Priming in item recognition: The organization of propositions in memory for text. *Journal of Verbal Learning and Verbal Behavior, 19,* 369–386.

McKoon, G., & Ratcliff, R. (1986). Inferences about predictable events. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 12,* 82–91.

McKoon, G., & Ratcliff, R. (1992). Inference during reading. *Psychological Review, 99,* 440–466.

McNamara, D. S., Kintsch, E., Songer, N. B., & Kintsch, W. (1996). Are good texts always better? Text coherence, background knowledge, and levels of understanding in learning from text. *Cognition and Instruction, 14,* 1–43.

Miller, J. R., & Kintsch, W. (1980). Readability and recall of short prose passages: A theoretical analysis. *Journal of Experimental Psychology: Human Learning and Memory, 6,* 335–354.

Mross, E., & Roberts, J. (1992). *The construction integration model: A program and a manual* (Tech. Rep. No. 92–14). Boulder: Institute for Cognitive Science, University of Colorado.

Murray, J. D., Klin, C. M., & Myers, J. L. (1993). Forward inferences in narrative text. *Journal of Memory and Language, 32,* 464–473.

Myers, J. L., & O'Brien, E. J. (1998). Accessing the discourse representation during reading. *Discourse Processes, 26,* 131–157.

Myers, L. M., O'Brien, E. J., Albrecht, J. E., & Mason, R. A. (1994). Maintaining global coherence during reading. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 20,* 876–886.

Noordman, L. G. M., & Vonk, W. (1998). Memory-based processing in understanding causal information. *Discourse Processes, 26,* 191–212.

Noordman, L. G. M., Vonk, W., & Kempff, H. J. (1992). Causal inferences during the reading of expository texts. *Journal of Memory and Language, 31,* 573–590.

Perrig, W., & Kintsch, W. (1985). Propositional and situational representations of text. *Journal of Memory and Language, 24,* 503–519.

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

Sanford, A. J., & Garrod, S. C. (1998). The role of scenario mapping in text comprehension. *Discourse Processes, 26,* 159–190.

Schank, R. C., & Abelson, R. P. (1977). *Scripts, plans, goals and understanding: An inquiry into human knowledge structures*. Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Schmalhofer, F. (1998). *Constructive knowledge acquisition: A computational model and experimental evaluation*. Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Schmalhofer, F., & Glavanov, D. (1986). Three components of understanding a programmer's manual: Verbatim, propositional, and situational representations. *Journal of Memory and Language, 25,* 279–294.

Seifert, C. M., Robertson, S. P., & Black, J. B. (1985). Types of inferences generated during reading. *Journal of Memory and Language, 24,* 405–422.

Singer, M. (1994). Discourse inference processes. In M. A. Gernsbacher (Ed.), *Handbook of psycholinguistics* (pp. 479–515). San Diego, CA: Academic.

Singer, M. (1996). Comprehending consistent and inconsistent causal text sequences: A construction–integration analysis. *Discourse Processes, 21,* 1–21.

Singer, M., & Halldorson, M. (1996). Constructing and validating motive bridging inferences. *Cognitive Psychology, 30,* 1–38.

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

Singer, M., & Kintsch, W. (2001). Text retrieval: A theoretical exploration. *Discourse Processes, 31,* 27–59.

Suh, S., & Trabasso, T. (1993). Inferences during reading: Converging evidence from discourse analysis, talk-aloud protocols, and recognition priming. *Journal of Memory and Language, 32,* 279–300.

Till, R. E., Mross, E. F., & Kintsch, W. (1988). Time course of priming for associate and inference words in a discourse context. *Memory & Cognition, 16,* 283–298.

Valencia-Laver, D. L., & Light, L. L. (2000). The occurrence of causal bridging and predictive inferences in young and older adults. *Discourse Processes, 30,* 27–56.

van den Broek, P. (1990). The causal inference maker: Towards a process model of inference generation in text comprehension. In D. A. Balota, G. B. Flores d'Arcais, & K. Rayner (Eds.), *Comprehension processes in reading* (pp. 423–445). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

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

van Elst, L., & Schmalhofer, F. (1998). *Integrative modeling of cognitive representations and social judgements with Concatex*. Unpublished manuscript, Department of Psychology, University of Heidelberg, Heidelberg, Germany.

Whitney, P., Ritchie, B. G., & Crane, R. S. (1992). The effect of foregrounding on reader's use of predictive inferences. *Memory & Cognition, 20,* 424–432.