THE CONSTRUCTION OF MENTAL REPRESENTATIONS DURING READING; INEFERENCES GENERATION

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To understand a text, a reader must use more than the individual words on a page. Readers integrate general knowledge in long-term memory with the written message to form a unified, coherent representation of text (Graesser, Singer, & Trabasso, 1994; McKoon & Ratcliff, 1992). There are multiple codes for mental representations. Language is only one such code, others being imagery, direct procedural representations, episodic representations, emotion, and so on. Theoretically, these representations can be embedded within one another or recoded to another form of representation to account for the complexity of thought. Even imagery and emotion are to be represented propositionally, not because they are by nature propositional, but for practical reasons.

For example, when one reads a story, individual words and sentences would be converted mentally into propositions and connected with each other through overlapping information or reference (e.g., pronouns) into a text base. These propositions would then be combined into macropropositions that defined the theme or gist of the story or some portion of it (e.g., goal, attempt, outcome). The macrorules that governed the combination of micropropositions into these macropropositional structures would emanate from a schema of some kind (e.g., story grammar).

Models of comprehension

There is wide agreement that text comprehension results in multiple levels of representation or codes. The levels include the representations of surface form; of the idea network, or "textbase"; and of the situations to which the text refers (van Dijk & Kintsch, 1983).

a. The first code was *verbatim text information or surface code*. The surface code is a record of the exact wording and syntax of the sentences. This surface code is preserved in memory for only a few seconds when technical **text** is read. Some information is remembered exactly or nearly exactly as given (e.g., the names of characters or places in a story).

b. The second code was *the propositional text base*. Just what is a proposition, anyway? Propositions are not seen as actual language; they have no form and are assumed to be the abstract, mental, meaning base of language. They cannot be experienced directly, have no objective reality, and are associated with no sensory modality (a description that also applies to schemata). A proposition is assumed to be composed of a predicate plus its arguments in the manner of case grammar. The predicate is typically a verb and the arguments are its agents (i.e., subject, object, and so on). The textbase is preserved in memory for several minutes or longer.

To illustrate a proposition, let us use an example. The sentences „John gave Marcel a map” and “A map was given to Marcel by John” would presumably share a common, underlying, proposition: (gave, was given) [agent: John, object: book, goal: Marcel]. The notation (gave, was given) denotes alternate surface structure forms; different syntactic arrangements can also be applied. Concepts like (gave, was given) are in turn defined by other associated concepts in the knowledge network such as the superordinate categories gift or transaction, the property transfer possession, and so on. These concepts are also in propositional form. Keep in mind that what are being presented on this page are not propositions but their surface structure notation, much as we diagram sentences in other ways. What is missing so far is an explanation of how we go from actual printed language or its linguistic notation to its abstracted, amodal, propositional, mental form.

The theory's answer to this question is that we have a schema for the proposition, a mental program composed of a predicate slot and argument slots. That is, the theory assumes a general, abstract schema for forming atomic propositions that is instantiated by reading each unit of a text. Furthermore, the theory proposes that there are script-propositions for the construction of emergent scripts, propositional schemata for generating propositional schemata that are presumably instantiated by instantiating the atomic proposition-schema. The layers of abstraction here are troubling.

These assumptions also seem to produce a contradiction in the theory. Schemata, in the form of prior knowledge structures such as story grammars or scripts, are rejected, but a propositional schema is accepted as the unit of thought and as a device for forming emergent scripts. The theory argues that prior knowledge structures, like scripts, are inflexible and insensitive to context while a predicate-argument schema is not limiting and can be constructed online. But why is a schema needed at the most basic level? Why not just a set of activated associations constrained by context at this level as well?

c. A third code was added and called the *situation model*. The situation model was not seen as part of the representation of the text proper but a mental representation constructed by each reader about the situation in the text (e.g., persons, actions, events). The form of the situation model was not specified, but

Perrig & Kintsch (1985) later proposed that the situation model could take the form of either a well-integrated text base or mental imagery. The situation model would contain causal chains of events that unfold as the key unlocks the door, a visual spatial image of the parts of the lock, and the goals of the person who uses the lock. The construction of an adequate situation model requires a sufficient amount of relevant world knowledge, such as general knowledge about locks and mechanical equipment. Deep comprehension consists of the construction of this referential situation model, whereas shallow comprehension is limited to the surface code and textbase. The situation model is retained in memory much longer than the textbase and the surface code, assuming that the comprehender has adequate world knowledge to build a situation model (Graesser, et al., 2002).

A major revision of the theory soon followed that dealt more deeply with prior knowledge use (Kintsch, 1988). The theory was modified into a two-stage, construction-integration model (CI).

The verbatim code, propositional code, and situation model code were retained, but the notion of schemata or any other stable prior knowledge structures in memory was eliminated. Instead, a loose associative network of prior knowledge was assumed in which there were stronger and weaker positive and negative connections between a vast array of concepts (i.e., propositions in memory). As a word or phrase is visually processed in a text, its many associates are activated in a spreading fan. This is the construction stage. This spread is very rapidly limited by the context to one or more most likely candidates. More and deeper context checks occur as the reader moves ahead until contextual constraints are satisfied and a stable interpretation emerges in the form of a text base and a situation model. This is the integration stage.

The CI theory is not an interactive one; it is initially bottom-up without priming, prediction, or any inferential top-down effects from prior knowledge. Context effects appear later to constrain the spread of alternative meanings. For example, in the unfinished sentence, “Call me...”, the phrase, call me, could take a variety of meanings, such as a telephone call or reference by name or descriptor. All such associations in the reader's experience would be activated bottom-up without discrimination but according to their associative strengths in memory. Further context would rapidly strengthen the more appropriate associations and inhibit the less appropriate ones, as in “Call me tomorrow” or “Call me Michael” or “Call me irresponsible”. Two shades of meaning co-occur in the old gag, Call me anything but late for dinner. As a coherent propositional text base emerges through further reading, a situation model could also be generated by the reader. These modifications to the theory offered several advantages including greater sensitivity to ambiguity and ever-changing contexts than formal, schema-driven processing would allow.

Constructing conceptual meaning

Conceptual meaning is seen as constructed anew in each situation by activation in the knowledge net and the parameters imposed on that activation by contextual constraints. In a mental lexicon, one looks up the meaning of a word, but in a knowledge network there is nothing to look up, so there is no such thing as lexical access. The conceptual meaning of a word is not fixed but probable; meaning is determined by the set of activated representations in the network in a given situation.

The idea that knowledge is a vast set of associations of differing strengths is not new and is shared by other cognitive theories (e.g., dual coding theory, semantic network theory). This view does not treat the meaning of words as fixed featural descriptions to be accessed but as an emergent quality the shades of which are determined by ever-changing contexts. Consistent usage in a culture allows us to define general meanings for dictionaries, but dictionaries are an external reference very different from the internal associations and references that occur from moment to moment in reading. Hence, the notions of lexicon and lexical access are misleading metaphors at best.

This view provides a perspective on meaning that is likely to find appeal among those of a constructivist persuasion. This view implies that meaning is a flexible, probabilistic, ever-changing entity that may never be the same twice. This does not imply that meaning is chaotic, that we can make a text mean whatever we want it to, or that there are not similarities between readers' readings or within the same reader upon reading a text again. There are constraints to be satisfied, and the constraints come from our own background memories as well as the conventions of our societies and cultures. We use printed language for lots of conventional reasons where close agreement on meanings is important. But how our mental networks construct a text representation can vary as we vary, and part of that variance is the depth to which we elaborate a text representation. The theory of meaning advocated here is not only constructivist but also minimalist. Clearly, readers can study a text over and over again and construct very elaborate meanings for its propositions and concepts. But most of the time, in reading or conversation, the process of meaning construction remains shallow, not just because comprehenders are inherently lazy but mostly because no more is required. A slight knowledge elaboration of a text is usually quite sufficient for whatever action is intended.

Cognition in general could be described as constraint satisfaction, particularly in situations that often involve verbal instructions such as problem solving and decision making. Following the construction-integration model, such cognitive acts would begin with the formation of an approximate but unintegrated local interpretation based on external input and the comprehender's goals and knowledge. This is followed by an integration phase that is essentially a constraint satisfaction process that rejects inappropriate local constructions in favor of those that fit together into a coherent whole. A variety of models of such processes are suggested for decision making, evaluation, motivation, emotion, and so on.

We concluded that comprehending text is a cognitive act; everything about the reading act also occurs in cognitive acts not involving reading. We perceive and discriminate, analyze patterns, make tentative interpretations, predict outcomes, resolve uncertainties, learn, appreciate, and perform other cognitive acts in material that is not in text form as well as in material that is in text form. That is, cognition in reading is a special case of general cognition involving printed language.

Inferences processing during reading

The process of creating a situation model allows readers to understand things that are not explicitly stated in the text. In these sense readers will draw inferences about the relation between events or the spatial relations between objects. For example, in comprehending the sentence, "*Three turtles were sitting on a log and a fish swam beneath them*" readers routinely infer that the „*fish swam beneath the log*" (Bransford, Barclay, & Franks, 1972). Inferences are a crucial aspect of language. Stevenson (1993), in a review of models of language comprehension, indicated that "linguistic processes are insufficient to account for the way we comprehend and remember sentences. Thinking, the ability to make inferences, is needed." Some inference processes seem to be automatic and effortless yet they yield quite complex kinds of information. Other inference processes seem to be dependent on the goals, strategies, and contextual situations of the readers. Some inferences are concerned with the relatively small units of reading represented by words; others are concerned with much larger units like event structures or story outlines Similarly, during the construction of a situation model, readers may attempt to explain causes of events as they proceed through a text (van den Broek, 1990).

For example, imagine a narrative in which the protagonist goes to the dentist one morning to get his wisdom teeth pulled. Later that night, his cheek is swollen. Drawing from a rich set of life experiences, a reader can easily infer that the character's visit to the dentist caused his cheek to be swollen. Comprehension of a passage therefore involves much more than the processing of individual sentences; it also involves the construction of a rich representation of the situation to which the text refers (Hess, Foss, & Carroll, 1995).

Another important aspect of the construction of situation models is its dynamic nature. Elements can fluctuate in terms of their availability in the reader's working memory as the reader proceeds through the text (Myers, O'Brien, Albrecht, & Mason, 1994; van den Broek, et al. 2001). To a certain extent, fluctuations of elements depend on their function in the context of the narrative. For example, with respect to causal information readers focus their attention on the last state or event that has causes but (as yet) no consequences in the preceding text (Fletcher, Hummel, & Marsolek, 1990).

Trabasso and van den Broek (1985) suppose that during the reading of the first sentences of a story, the reader constructs a hypothetical world based on the characteristics of the hero, the place, the time, etc. This hypothetical world establishes a set of circumstances in the light of which the subsequent events will be interpreted. The possible world will change as causal changes occur, and this is why causal inferences are so important. Making these inferences is central to the "causal inferencemaker" model (Van den Broek, 1990). Inferences are made in two directions: *backward, forward and orthogonal.*

(a). **Backward inferences** correspond to inferences of connection: they link a focal event (which has just been read) to one or more previous event(s), to maintain the coherence between distinct events.The backward process is subject to two types of constraint: the criteria required for the causal relation, and the availability of the information in the memory. A reader reads an event B, and tries to connect it with a previously read event A. If A satisfies the criteria for a causal relation, the process stops; if A does not comply with these criteria, there is a break in the coherence. Two solutions are possible:

- either the reader finds in his/her memory one or more previously described events that allow him/her "to re-establish" the causal relation;

- or the reader constructs an elaboration involving an event that is not explicit in the **text**. This elaboration must be compatible with the stored information, and depends (as we have already pointed out) on the reader’s knowledge of events and on causality in general.

(b) When the described events generate expectations concerning what will happen later, this is a **forward process**. These **inferences** are not required to understand the **text**, but they can facilitate (or hinder) the treatment of subsequent events. Forward inferences anticipate future events by means of cataphors, the anticipation of the future relevance.

Akerman & al. (1991) distinguish between two types of forward **inferences**: those connected solely to the anticipation of events, and those that also estimate the importance of the previous events for those that are going to occur. So, to take the example used by McKoon & Ratcliff (1992): "the actress fell from the 14 floor". The degree of sufficiency is such that it authorizes a specific expectation: "she died "; but if we read the sentence "the actress fell through the window", this suggests physical injuries but not their extent. So it is the degree of sufficiency that is going to determine the specificity of the inference produced. This model is based on the idea that a reader who reads a description of an event always tries to find a causal justification for it.

(c) Orthogonal inferences embellish the focal statement by providing details or associations.

Most important for comprehension, the combined patterns of activation may result in a connecting backward inference that integrated the focal event with representation of the prior text. If the connecting inference provides referential and causal coherence, no further inferential processes are needed for comprehension, and the reader proceeds to the next statement.

A more complicated situation arises when simple associations do not provide adequate coherence. When this happens, the lack of coherence evokes additional coherence-based processes. A search results, in which prior text is reactivated and background knowledge is accessed.

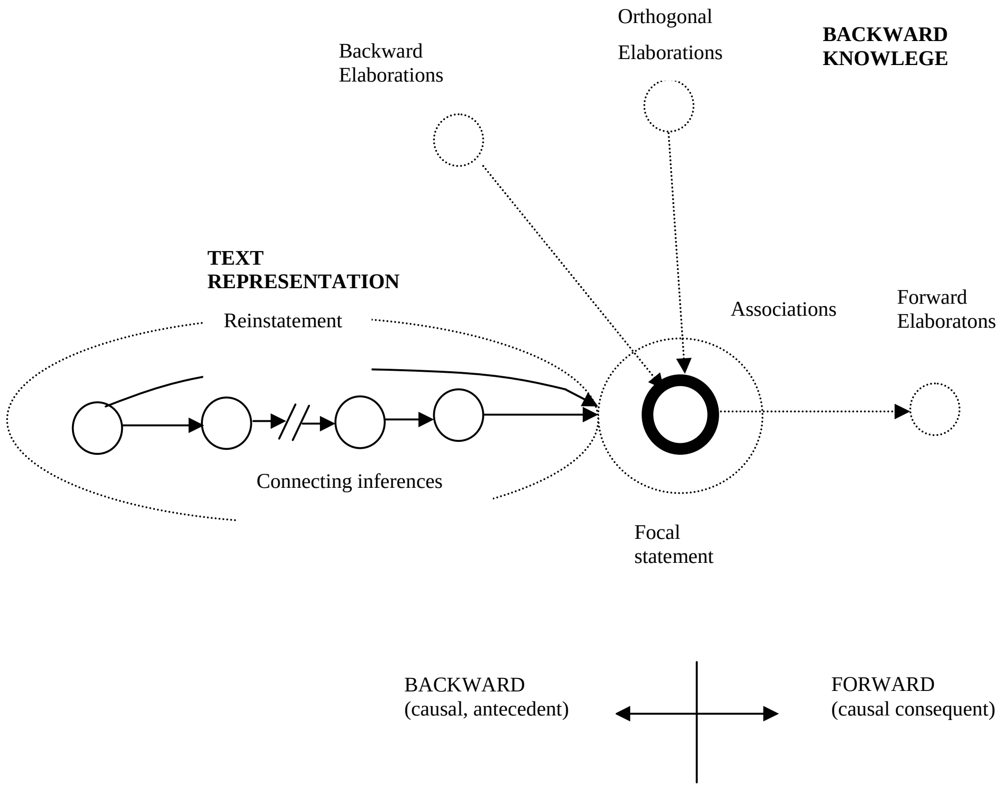
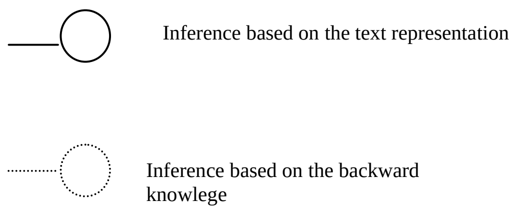


Fig. 1. A process model of inference generation during reading (apud van den Broek, 1994)



If the patterns of activation that results from the search and those that are based on the focal statement yield adequate anaphoric or causal, reinstatements or elaborative backward inferences are generated. Coherence is established, and the inferential process stops.

There are variations in the extent to which particular types of inferences or activations are made (Singer, 1994), and researchers have become increasingly interested in determining the circumstances that lead to particular inferences (Narvaez, van den Broek and Ruiz, 1999). A considerable number of studies have focused on the effects of reader characteristics on inferential activity. For example, inferences have been found to differ as a function of language skill (Horiba, 1990; Horiba, van den Broek, & Fletcher, 1993; Zwaan & Brown, 1996), reading ability (Wolman, 1991; Wolman, van den Broek, & Lorch, 1997), background knowledge (readers with expert background knowledge do more explaining; (Chi, Feltovich, & Glaser, 1981; Chiesi, Spilich, & Voss, 1979), and analysis (Lundeberg, 1987; Wineberg, 1991).

Conclusions

When we comprehend a text, understanding something we building a mental representations of the described state of affairs, situation models. To do so, we must form connections between things that were previousely disparate: the ideeas expressed in text and relevant prior knowledge. Comprehension implies forming coherent wholes of elementary perceptual and conceptual features. That is, we construct bottom-up, local interpretations that are integrated via constraint satisfaction process.

Comprehension in the construction-integration model is an activation-based process that proceeds in two phases. The construction phase produces local sentence-level propositions using simple, context-independent rules. The integration phase uses a constraint satisfaction process to integrate the possibly incoherent set of local propositions into a coherent whole organized by higher level macropropositions. Many of the CI model's predictions about anaphora resolution, word identification, and the generation of infernces have been empirically confirmed.

The process of creating a situation model allows readers to understand things that are not explicitly stated in the text. To achieve these goals, readers will draw inferences about the relation between events described by the text..

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