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Introduction

Advances in Text Comprehension: Model, Process and Development

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SUMMARY

To a very large extent, children learn in and out of school from written text. Information Communications Technologies (ICT) offers many possibilities to facilitate learning by confronting children with multimodal texts. In order to be able to implement learning environments that optimally facilitate children's learning, insight is needed into the cognitive processes underlying text comprehension. In this light, the aim of this special issue is to report on new advances in text comprehension research in perspective of educational implications. Starting from recent theoretical frameworks on the cognitive processes underlying text comprehension, the online processing of text will be discussed in adults and in school children. Copyright © 2008 John Wiley & Sons, Ltd.

MODELING TEXT COMPREHENSION PROCESSES

It is generally agreed upon that the understanding of written text calls upon both bottom-up word recognition processes and top-down comprehension processes (e.g. Perfetti, 1999). Interactive models of reading comprehension (e.g. Kintsch, 1998; Just & Carpenter, 1987) therefore provide the best framework for the study of individual variation in the development of reading comprehension. Comprehending texts involves the flexible use of different sources of information, including in some cases, the integration of linguistic information with graphic information. During the past decades, research on text comprehension has moved towards models in which memory-based and constructivist aspects of comprehension are more integrated. Taking an integrated model of text comprehension as a starting point, important questions are how online text processing can be modelled, how it actually takes place, and how children learn to develop text comprehension skills. In order to be able to address such questions, a blueprint model of the reader is given in Figure 1 (also see Perfetti, 1999).

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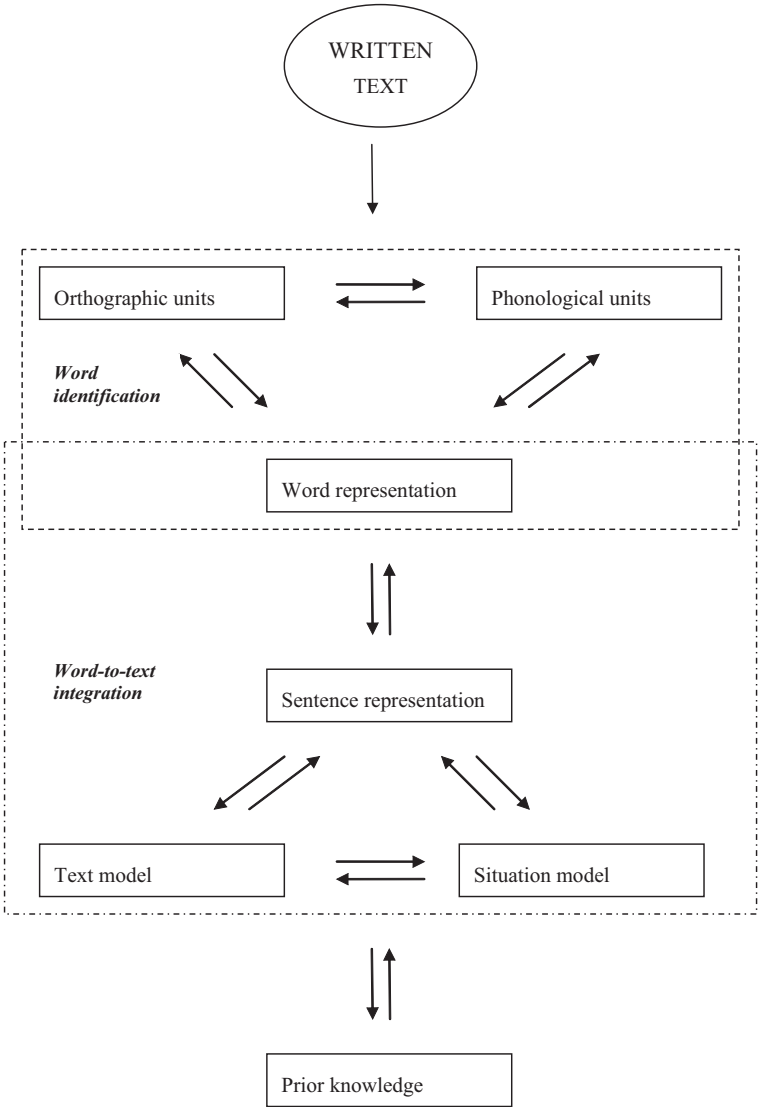

Figure 1. Model of the reading comprehension process

The reading of text starts with the identification of individual words, i.e. the processes which convert the visual input into a linguistic representation. The lexical quality hypothesis (Perfetti & Hart, 2001) expresses the basic idea that reading skill among readers is supported by their knowledge of words, including the precision of the reader's representation of orthography, phonology, morphology and meaning. Word decoding or the accurate and fast retrieval of the phonological code for written word forms is commonly assumed to play a central role in reading and the development of such. More specifically, the automatization of word decoding skills and attainment of fluent reading levels is essential for the development of word decoding (Perfetti, 1992; Samuels, 1994; Stanovich, 2000). Central to a Parallel-distributed-processing account of word decoding is the fact that

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the processing of both regular and irregular word forms is explained in terms of a single associative network (cf. Plaut, McClelland, Seidenberg, & Patterson, 1996). Whereas 'known' forms are recognized more or less directly, rare or complex forms are often recognized via parsing or the segmentation of the word in its morphological constituents. Van Orden and Goldinger (1994, 1996) have proposed even greater mediation of the process of word recognition, which they define as the outcome of the interactions between phonological, visual and meaning information in recurrent subsymbolic networks. Phonological connections are further assumed to play a critical role in the consistency of word decoding. Automatic word recognition subsequently enables the devotion of mental resources to the meaning of a text and thus allows readers to clearly use reading as a tool for the acquisition of new information and knowledge (NRP, 2000; Perfetti, 1998; Samuels & Flor, 1997; Spear-Swerling & Sternberg, 1994).

As a next step, text comprehension requires word-to-text integration. Understanding sentences requires the identification of words. As a word is identified, the reader connects it to a continuously updated representation of the text. Studies of eye movements (Just & Carpenter, 1992; Reichle, Pollatsek, Fisher, & Rayner, 1998) have revealed some important aspects of sentence comprehension during reading. First, it was found that even skilled readers fixate on most of the words they read. This seems to imply that word identification is at the heart of reading comprehension. In addition, it was shown that interpretation immediately follows recognition ('immediacy assumption'), and that fixations tend to be longer at the end of sentences. The latter finding indicates that integrative comprehension processes must particularly take place at sentence endings. Sentence comprehension can at best be understood as an operation which uses both sentence structure and word meanings to formulate hypotheses about the meaning of the sentence. The immediacy assumption, derived from studies of eye movements during reading, expresses this idea at the general level (Just & Carpenter, 1992). On the basis of syntactic processors, sentence constituents may be identified. Different theories about how words are attached to syntactic structures (MacDonald, Perlmutter, & Seidenberg, 1994; Frazier & Clifton, 1996) agree on the conclusion that each word is immediately attached to a syntactic phrase. Neurocognitive studies also provide evidence for an ERP component sensitive specifically to processes that determine constituent structures (Hagoort, Brown, & Groothusen, 1993; Hagoort, 2005). Beyond the attachment of a word to a syntactic phrase is the attachment of a word's referential meaning to a semantic representation of the text. In this way, word-by-word processing leads to word-to-text integration. This referential integration is necessary to maintain comprehension of the situation described by the text.

To arrive at text comprehension, the reader must combine the meaning of each sentence with the message accumulated up to that point on the basis of prior text. This memory-based position sees comprehension as the product of evaluations of the information from text. Major models of text comprehension, such as the construction-integration model (Kintsch, 1988), the landscape model (van den Broek, Risden, Fletcher, & Thurlow, 1996) and the resonance model (Gerrig & McKoon, 1998), have shown that text comprehension cannot be done with only the information present in the text, but that individuals also use their prior knowledge to construct new knowledge that is relevant to their individual experiences and situations. The propositional structure of the contents of a passage is said to delineate two types of structures: a micro-propositional structure referring to the coherence of propositions which are in close proximity in the text, on the one hand, and a macro-propositional structure specifying a more global level of meaning, on the other hand.

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In this line of thought, it is claimed that readers construct situation models as they attempt to comprehend text. During this process, two levels of representation are involved: a model of the propositions of the text (the text model) and a model of what the text is about (the situation model). The basic meanings are extracted from the sentences, progressively built up by reading successive sentences and supplemented by inferences in order to make the text coherent. Because texts cannot be fully explicit, there are abundant opportunities for the reader to make inferences about what is in the text on the basis of prior knowledge. It is this level of comprehension that reflects 'situation' information and requires additions to linguistic-based accounts. A situation model may help the student to identify and define problems, to specify reasons for problem solution, to generate strategies for solving identified problems and to observe results of attempted solutions (cf. Zwaan, Kaup, Stanfield, & Madden, 2001). The basic premise is that text comprehension involves the mental simulation of the referential situation, and that these mental simulations are constrained by the linguistic and pictorial information in the text, the processing capacity of the human brain and the nature of human interaction with the world (Zwaan & Radvansky, 1998). Situation model components include information from the text,

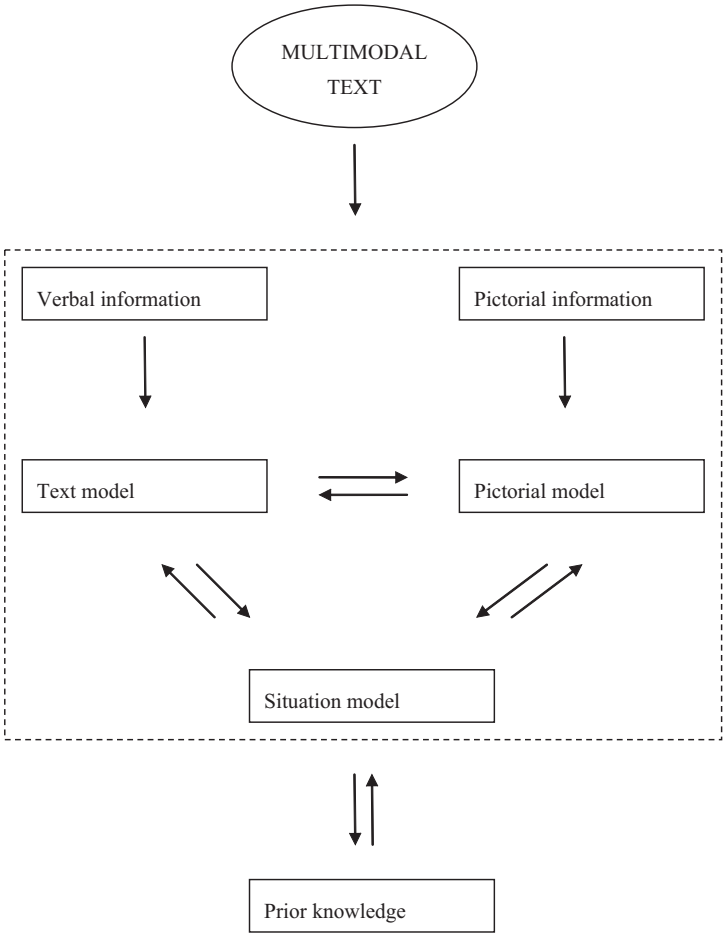

Figure 2. Modelling multimodal text processing

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inferences based on the text, relevant prior knowledge and inferences that relate the text and prior knowledge (see Singer, Graesser, & Trabasso, 1994; Kintsch, 1998).

If we add to these situation components other sources of information that a reader might have in a specific instructional situation, learning from text becomes an even more extended problem. For example, in educational settings, there is a widespread belief that Information Communications Technologies (ICT) offers many possibilities to facilitate knowledge construction (cf. Mayer, 2001). Because ICT is increasingly being integrated into the school curriculum, the convergence of instruction of school subjects and networked technologies seems inevitable. Therefore, it becomes crucial to examine how students learn from multimodal text. The basic question is how a mental simulation of the referential situation is built up on the basis of the linguistic and pictorial information in the text. The cognitive theory of multimedia learning (Mayer, 2001, 2005) is based on the idea that there are separate processing systems for the two sorts of information, and that these channels show a limited processing capacity. In Figure 2, the components which are involved in multimodal text processing are graphically displayed.

The processing of verbal information usually involves the comprehending of written text which can be seen as a secondary language process partly derived from primary spoken language processes. The comprehension of verbal information involves the identification of words, the processing of sentences and the construction of text models along the lines as described before. The comprehension of pictorial information involves the construction of pictorial models. According to Paivio's (1986) dual coding theory, the two coding systems are supposed to be interconnected. It has also been found that pictorial information can help comprehending complex expository text (Marcus, Cooper, & Sweller, 1996; Schnotz, 2005). However, how the two sources of information get integrated and in what way cross-modal information sources help the student building a situation model is still unclear.

THIS SPECIAL ISSUE

In this special issue, an attempt is made to shed light on advances in text comprehension research. Starting from current operational models of the cognitive processes underlying text comprehension, the online processing of text is examined in adults and in children learning to read. In the initial set of four papers, the focus is on reading comprehension in adults. In three additional papers, the comprehension of text is studied from developmental point of view the processing of multimodal texts in adults and children is dealt with.

In the first paper, Perfetti, Chin-Lung and Smalhofer examine comprehension skill differences in the processes of word-to-text integration, by which a reader connects the meaning of a word, as it is read, to a representation of the text. On the basis of two studies using Event Related Potentials (ERPs), which provide fine-grain temporal data on word-to-text processes, they conclude that less skilled comprehenders are slow to integrate a word with its preceding context. ERP methods allow word-by-word reading data without explicit responding, while adding the possibility of inferences about some of the processes that occur when a word is identified and connected to its context. A particular ERP component, the N400, has proved to be a marker of semantic processing thanks to its sensitivity to context. In their studies, word-to-text integration processes were reflected in N400 indicators when a critical word had an explicit link to a word in the prior text and when its meaning was a paraphrase of a prior word. Compared with skilled comprehenders,

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adult less skilled comprehenders showed delayed and less robust ERP effects, especially when meaning paraphrase was the basis of the integration. It is this finding that comprehension skill is associated with the ability to use meaning relations between words in the word-to-text integrations process that is the most intriguing. It implies that the adaptive use of word knowledge in context is an important component of reading comprehension skill and directs attention to individual differences in lexical quality as a source of individual differences.

In the second paper, Kaakinen and Hyönä investigate the influence of a reading perspective on on-line processing and memory of narrative texts. More specifically, they examine whether prototypical prior knowledge related to the reading perspective and the transparency of relevance of the text information influence reading and memory of a narrative. In their paper, the authors report on the results of an eye-tracking experiment which examines whether the perspective-driven text comprehension framework applies to the comprehension of narrative text. Participants were instructed to adopt either a burglar's or an interior designer's perspective. A pilot test showed that readers have more overlapping prior knowledge with the burglar-relevant than with the interior designer-relevant information of the experimental text. Participants read either a transparent text version that made apparent the irrelevance of text segments to a given perspective or an opaque text version that did not mention the relevant perspective. After reading, participants wrote a free recall of the text. The results showed that perspective-related prior knowledge modulates the perspective effects observed in on-line text processing and that signalling of (ir)relevance helps in encoding relevant information to memory.

In the third paper, Van den Broek and Kendeou discuss the effects of misconceptions on the on-line comprehension process during reading of science texts with an eye towards developing ways to encourage revision of these inaccurate ideas. To determine whether such differences in processing indeed occur, two empirical experiments on the on-line processing of refutation and non-refutation science texts by readers with and without misconceptions related to the topics of the text were conducted. In Experiment 1, a think-aloud methodology was employed because it allows the consideration of a variety of reader responses. In Experiment 2, a reading time methodology was employed because it is unobtrusive and is sensitive to both conscious and subconscious processes. The results indicate that texts that promote co-activation of misconceptions and correct information (refutation texts) elicit fundamentally different comprehension processes in readers with misconceptions than do texts that do not promote co-activation (non-refutation text). When reading the refutation texts, readers with misconceptions read the sentences with correct information more slowly and engaged in more conceptual change behaviours than when reading the non-refutation texts. Thus, the co-activation of misconceptions and correct information led readers with misconceptions to experience conflict and allowed them to engage in efforts to repair the conflict and create coherence. In contrast, readers with misconceptions who read the non-refutation did not slow down or engage in conceptual change behaviours more than readers without misconceptions.

In the fourth paper, Gyselinck, Jamet and Dubois deal with the role of working memory in multimodal text comprehension. Their account is based on the idea that there are separate processing systems for auditory-verbal and visual-pictorial information, each of which has a limited processing capacity at any given time. In order to come to a better understanding of the processes involved in the integration of information from multiple sources, a series of experiments were conducted with complex multimedia material the

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working memory hypothesis as an explanation of the classical modality effect. Overall, the experiments show that even in cases where subjects have to navigate between different types of information and have to integrate various items of information, the verbal storage component of working memory is important in permitting comprehension. Storage of verbal information does not, however, depend on the modality of presentation and the classical modality effect appears to depend on individual differences. Even in cases where subjects have to navigate between different types of information, the verbal storage component of working memory is important in permitting a processing operation that is as complex as comprehending. The results also show that visuo-spatial working memory is involved, irrespective of whether visuo-spatial information is presented in the form of illustrations of a text or conveyed by the text itself. It is claimed that these results confirm the view that the working memory is concerned primarily with representational channels (verbal and pictorial information) instead of sensory channels (auditory and visual information).

In the fifth paper, Segers, Verhoeven and Hendrikse focus on cognitive processes underlying children's multimedia text learning. These processes were studied using a self-paced task and authentic school texts with mostly representational pictures in an elementary school setting. Both the quantity and quality of learning were assessed immediately following intervention and 1 week later. In a within-subjects design, all of the children were taught four lessons of a different format: written presentation only; written presentation accompanied by pictures; oral presentation only; and oral presentation accompanied by pictures. With respect to the quantity of learning, a short-term modality effect was found with oral presentation producing better results than written presentation when accompanied by pictures. A multimedia effect was found for only the oral conditions. With respect to the quality of the children's learning, an initial short-term modality effect was found but reversed 1 week following intervention with no evidence of a multimedia effect. The modality effect (which refers to the added value of oral vs. written text both accompanied by pictures) was replicated for the quantity of short-term learning. Oral presentation with pictures produced better short-term performance than written presentation accompanied by pictures. One week later, however, the detected difference was gone.

In the sixth paper, Rouet and Coutelet focus on the acquisition of document search strategies in 9- to 13-year-old students in two separate studies. In study 1, they investigated children's ability to search a junior encyclopedia in order to answer factual questions. Consistent with previous studies, they found that the task was very difficult for third graders, who frequently faced problems with word definitions, text organizers and search devices, or when having to design alternate search strategies. Search time decreased sharply in the fifth and seventh grades, as the success rate increased. Some fifth graders did attempt to use a top-down strategy, but it was mainly based on the table of contents, which sometimes only resulted in more confusion. Only at the seventh grade level, did children use the dominant top-down strategies based on the index to locate specific keywords. Study 2 aimed at confirming the trends observed in study 1 in a more controlled setting, using one-page documents instead or a whole book. They found older students to rely more systematically on the content organizers (i.e. headings, keywords) inserted in the text. The researchers observed a sharp increase in performance, as well as thorough qualitative changes in children's approach to the task. Put together, the results suggest that information search calls upon specific cognitive processes, such as multi-tasking and relevance checking that increase developmentally with schooling.

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In the seventh paper, Verhoeven and Van Leeuwe examine the predictors of reading comprehension development of children throughout the primary school years. Specific effects of word decoding, vocabulary and listening comprehension abilities on the development of reading comprehension were longitudinally examined for a representative sample of Dutch children throughout the elementary school period. An attempt was made to test two theoretical frameworks for the prediction of the development of reading comprehension: the lexical quality hypothesis in which word decoding and vocabulary are assumed to be critical determinants of reading comprehension and the simple reading view in which reading comprehension is assumed to be the product of word decoding and listening comprehension. The results showed significant progress across grades on all of the predictor and criterion measures. The stability of the measures was also high across time, which shows the individual differences between students remain across grades. The data provide empirical support for the lexical quality hypothesis as they show knowledge of word forms and word meanings (i.e. vocabulary) to predict the development of reading comprehension. Support for the simple reading view was also found in that word decoding and listening comprehension significantly predicted reading comprehension as well. However, the associations between listening comprehension and reading comprehension throughout the elementary grades were largely reciprocal, which is in keeping with the idea that the development of reading comprehension entails the development of listening comprehension and vice versa.

The final contribution to this special issue comes from Art Graesser. He presents a concise commentary on the research-based papers being presented and a short perspective on text comprehension research in the future.

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