Representation of Knowledge in Memory: Evidence from Primed Recognition

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Abstract

This paper investigates the relationship readers with different levels of prior knowledge construct among procedural text elements, specifically, among the goal, the actions and the outcome of a procedural text. Readers were either beginners, intermediates, or experts in using a particular software. Our hypothesis was that the main difference between the prior knowledge organization of beginner, intermediate, and advanced subjects was due to the relationship among a goal, the necessary actions to attain this goal, and the obtained outcome. An experiment using a primed recognition task with the goal as prime and both the outcome and the actions as targets confirmed this hypothesis. The primed recognition results were simulated with the Construction-Integration model of comprehension (Kintsch, 1998).

Introduction

Many studies have shown that remembering and learning from text depend on both textual characteristics and the cognitive properties of readers. Kintsch (1994) demonstrated that with explanatory texts, remembering, and even learning, was better or occurred more quickly when the exposed concepts were just beyond the current state of the reader's knowledge. McNamara, Kintsch, Songer & Kintsch (1996) showed that when the coherence of a text was weakened, e.g., nouns were replaced by pronouns, and descriptive elaborations and connectives were removed, the readers with prior knowledge used compensatory comprehension processes to infer the relations not stated in the text (see also McNamara & Kintsch, 1996). Other researchers have demonstrated an interaction between the readers' prior knowledge, and the textual semantic structure (Caillies, Denhière & Jhean-Larose, in press; Caillies & Denhière, in press). In these studies, two versions of a procedural text, causal and teleological, were presented to three groups of learners: beginners, intermediates and advanced. Results showed that the hierarchical organization of textual information facilitated the comprehension of advanced subjects and that the temporal-causal organization facilitated the comprehension of beginner and intermediate subjects.The authors argue that the interaction was due to the similarity of the structure of prior knowledge and the organization of the text: texts which are hierarchically organized in a goal/sub-goals structure are optimal for the advanced subjects, and texts which are organized in a temporal-causal chain are optimal for the beginner and intermediate subjects.

Based on these results, we believe that the main difference between the prior knowledge organization of the beginner and the advanced subjects lies in the relationship among the goal, the necessary actions to attain the goal, and the obtained outcome (Trabasso & van den Broek, 1985; Baudet & Denhière, 1991). Our predictions were based on the assumption that: (a) for advanced subjects, the goal and the outcome are directly and strongly associated in memory while the actions necessary to attain the goal are subordinated; (b) for intermediate subjects, the goal and the outcome are loosely connected, and the outcome is more related to the actions they need to reach the goal; (c) for beginner subjects, the type of relationship they establish among the goal, the outcome, and the actions varied according to their order in the text. Given these assumptions, we expected an effect of prior knowledge structure on encoding and on retrieval of information. In our study, we therefore focused on input activities as measured by the reading times of the different type of sentences -- goal, actions, and outcome-- as well as output estimated by the retrieval of this information in memory. This was done with a primed recognition task, with either a goal or a control sentence as primes, and either outcome or action sentence as targets (McKoon & Ratcliff, 1992; van den Broek & Lorch, 1993).

Simulations carried out with the Construction-Integration model and presented after the experimental investigation were run to account for the effect of prior knowledge structure on the retrieval of information (Kintsch, 1998). According to the Construction-Integration model, knowledge is represented as an associative network, the nodes of which are concepts and propositions. Text is processed in cycles roughly corresponding to a sentence, and two phases, construction and integration, are involved in sentence comprehension. The construction phase takes as input a serie of concepts and propositions.

As an example, the sentence:
Select the paragraph to be printed,
corresponds to the following propositions:
P1 Paragraph
P2 TOBEPRINTED [P1]
P3 SELECT[P1]

Propositions are connected each other based on referential coherence (Tapiero & Denhière, 1995): the proposition 2, like the proposition 3 will be connected to the proposition 1. The integration phase is characterized by a process of diffusion of the activation, reinforcing the propositions appropriate to the context and inhibiting and deactivating the irrelevant elements. This results in a memory representation that is locally and globally well structured, and that can be represented as a coherent propositional network. From this representation, a reader can recognize sentences, answer questions, and so on.

Experiment

We assume that reading and primed recognition times should be shorter for advanced than for intermediates, with those of beginners subjects being the longest. We further expect an interaction between prior knowledge and target type for the goal primed recognition times: For advanced and intermediate subjects, it should take longer to recognize the actions than to recognize the outcome, this difference being greater for advanced than for intermediates; for beginner subjects, without prior relevant knowledge, the target recognition time will be a function of the text surface distance between the prime goal and the target (action 1 < action 3 < outcome). We expect a larger goal priming effect for beginner than for intermediate subjects, and for intermediates than for advanced subjects. For advanced subjects, the recognition times will be the same for both goal and control primes because these two types of prime equally affect the reactivation of the subjects' episodic goal structure (Ericsson & Kintsch, 1995).

Method

Participants

Fifty four students from Montpellier (France) participated in the experiment. They differed in their knowledge of the text editor Word and the spreadsheet Excel: 18 were beginners, 18 were intermediates, and 18 were advanced users. All participants read and recognized six texts. They were assigned to one of the three groups according to their prior knowledge, mesured by their scores obtained in a questionnaire designed to test their knowledge of Word and Excel.

Material

Six procedural texts were constructed: three describing the use of Word™ and three describing the use of Excel™. Each text was composed of three sequences, each sequence contained a goal, four ordered actions, and a outcome always presented in this order.

An example of text is presented below.

To print a paragraph, it is necessary to perform the following three sequences of actions.
Sequence 1
Select the paragraph to be printed
Position the cursor at one extremity of the paragraph
Press the mouse button
Place the cursor at the other extremity
Press simultaneously the "Shift" key and the mouse button
The paragraph appears in video-inverted type
Sequence 2
Select the "Print..." command
Position the cursor on the "File" menu
Keep the finger pressed on the mouse button
Choose the "Print..." command
Release the mouse button
The "Print " dialog box appears on the screen
Sequence 3
Print the paragraph
Type the desired number of copies on the keyboard
Put a quotation in the option button " Print selection only" with the mouse
Position the cursor on "OK"
Press the mouse button
Word throws the impression of the paragraph

The sentences to be recognized were preceded either by a goal prime sentence, such as "Select the paragraph to be printed," or by a control prime sentence, such as "Remember this text" The true targets could be the action 1, the action 3, or the outcome of the sequences. Twelve pairs of sentences were presented after each text reading, 6 true targets and 6 false targets. Four comprehension questions were constructed to make sure that subjects read in order to understand.

Procedure

Each subject read all six texts. After reading a text, presented one sentence at the time self paced, subjects performed the primed recognition task and answered four comprehension questions.

Results

Reading time

The repeated measures ANOVA conducted on the reading times per word revealed a marginally significant effect of prior knowledge, $F_1(2,51) = 2.77$, $p < .07$; $F_2(2,150) = 74.08$, $p < .01$, mainly indicating that the average reading time was significantly longer for beginner subjects ($M = 388$ ms) than for intermediate ($M = 354$ ms) and advanced subjects ($M = 323$ ms), $F_1(1,51) = 4.29$, $p < .05$; $F_2(1,150) = 106.23$, $p < .01$.

Primed recognition

Two 3 x 2 x 3 analyses of variance of yes responses were conducted: one for the correct recognition time per word, and one for the recognition errors. Prior knowledge was used as a between factor (beginners, intermediates, and advanced), and both Prime (goal and control), and Target (outcome, action 1, and action 3) as within factors.

While the effect of prior knowledge was not significant for recognition errors, the mean recognition time was significantly shorter for the beginners than for the other subjects (M = 255 ms vs M = 334 ms), $F_1(1,51)$= 18.59, p < .01; $F_2(1,20)$= 147.65, p < .01.

The interaction of knowledge and target was significant for recognition times, and mainly indicated that the difference in recognition time between the outcome and the two other targets was smaller for beginner subjects than for the two other groups, $F_1(1,102) = 7.38$, $p < .01$, $F_2(1,20) = 5.95$, $p < .01$, and it was smaller for intermediate than for advanced subjects $F_1(1,102) = 3.79$, $p < .05$, $F_2(1,20) = 3.58$, $p < .05$, whereas the action 1 and the action 3 did not significantly differ.

The Knowledge by Target by Prime interaction was significant in the subject analysis $F_1(4,102) = 3.06$, $p < .02$, and marginally significant in the item analysis $F_2(4,20) = 2.37$, $p < .09$ (see Table 1). This interaction mainly indicated a goal priming effect on action 3 for intermediates, and a goal priming effect on action 1 for advanced. For each knowledge group, analyses showed the following results:

For beginners, the Prime by Target interaction was significant, $F_1(2,34) = 3.62$, $p < .05$; $F_2(2,10) = 4.87$, $p < .05$, and indicated that the difference between goal and control conditions was greater for the action 1 than for both the outcome and the action 3, $F_1(1,34) = 6.88$, $p < .05$; $F_2(1,10) = 9.53$, $p < .01$. The action 1 was faster recognized than the two other targets only when the prime was the goal.

For intermediates, the Prime by Target interaction was not significant. Althought the recognition times of the three targets did not significantly vary as a function of the nature of the prime, the outcome and action 1 targets were faster recognized than the action 3, $F_1(1,34) = 8.54$, $p < .01$; $F_2(1,10) = 3.86$, $p < .08$.

For advanced, the Prime by Target interaction was also not significant. Target effect showed that the outcome target was significantly faster recognized than both the action 1 and the action 3, $F_1(1,34) = 35.04$, $p < .01$; $F_2(1,10) = 15.28$, $p < .01$, that did not differ.

Table 1: Mean recognition time of the three true targets as a function of the prime and of the prior knowledge.

	Prior knowledge		
	Beginners	Intermediates	Advanced
Goal prime			
Action 1	230	345	335
Action 3	254	344	360
Outcome	250	317	286
Control prime			
Action 1	279	325	344
Action 3	267	389	345
Outcome	252	332	298

Discussion

The analysis showed that subjects with different level of prior knowledge differ regarding to reading times and to yes recognition times but not regarding to yes recognition error. Indeed, we observed that the reading time was the shortest for the advanced, and the longest for the beginners whereas the recognition time of the true target was shorter for the beginners than for the intermediate and advanced subjects.

Consistent with our hypothesis, the prior knowledge by target interaction was significant, and mainly indicated that the difference between the outcome and the actions was smaller for the beginner subjects than for the other knowledge groups, and was smaller for intermediates than for advanced.

The significant Condition by Target by Knowledge interaction demonstrated a goal priming effect on the recognition times on the actions 1 and 3 but no goal priming effect on the recognition time of the outcome, which is consistent with our assumption. As we predicted, the separated analyses indicated that the relationship subjects with different levels of knowledge established among a goal, the actions and the obtained outcome differed. The beginner subjects recognized faster action 1 close to the goal in the surface structure than the other targets (action 3 and outcome) when the prime was the goal, whereas the intermediate and advanced subjects always recognized fastest the outcome (which was distant from the goal in the surface structure), for all priming conditions.

Simulations

Simulations carried out with the Construction-Integration model (Kintsch, 1998) were used to reproduce the recognition results. These simulations are based on the assumption that the readers used referential coherence to construct textbase representation (Tapiero & Denhière, 1995) and that differences in recognition performance between beginner and advanced subjects were due to the activation of different prior knowledge structures: a temporal-causal network for beginners and a goal hierarchy for advanced users. Our main purpose was to simulate the effect of prior knowledge structure on the elaboration of an episodic structure during reading and on the retrieval of stored information.

The first step involved in the simulations was to construct a network of the textual representional units and their interrelations. The second step was to elaborate a prior knowledge network assumed to represent the prior knowledge structure of beginner, intermediate and advanced subjects. In the beginner knowledge network, the goal, the actions and the outcome of each sequence are related according to their order in the text, whereas in the advanced network, the goal and the outcome are strongly and directly associate, and actions subordinate (see figures 1 and 2). In the intermediate network, the goal and the outcome are loosely connected and the actions are related to the outcome according to their presentation order in the text.

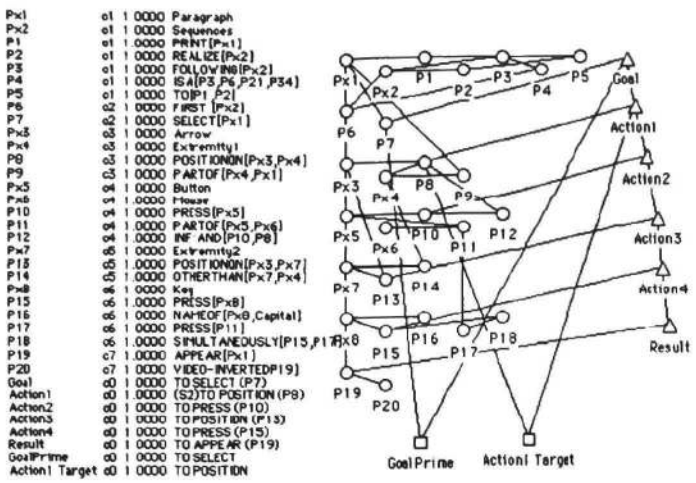

Figure 1: Network of the sequence 1 of a text with beginner prior knowledge network.

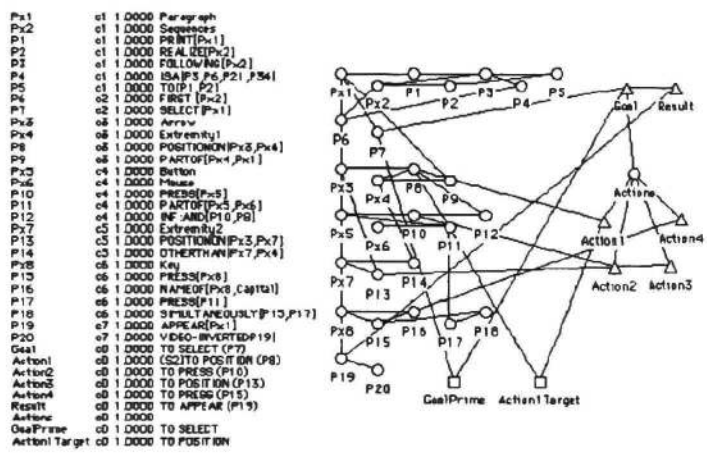

Figure 2: Network of the sequence 1 of a text with advanced prior knowledge network.

We postulate that during comprehension textbase elements may retrieve elements of the knowledge net. Indeed, at each processing cycle, we linked prior knowledge nodes to the corresponding textbase nodes. These knowledge nodes were linked to those of the textbase according to the assumption that this knowledge access is not resource consuming (Ericsson & Kintsch, 1995). Separate reading simulations were performed for the beginner, the intermediates and the advanced subjects. The number of links created between the textbase and the prior knowledge networks was the same for each knowledge group (n=6). We did simulations in order to obtain an activation value in long term memory for each node. This value represented the weight in memory of the concept or of the proposition.

To simulate the retrieval of information with the Construction-Integration model, we linked a test node to the textbase. The test node included the appropriate prime, the goal of the sequence, and a target, either the actions (1 or 3) or the outcome. A series of 9 retrieval simulations for each knowledge group was run: 3 for each of the three text sequences, and target types (action 1, action 3, outcome). Thus, we obtained activation values for each target of each sequence: outcome, action 1 and action 3.

We correlated our recognition time with the activation values obtained with the Kintsch's construction-integration model. The activation values obtained are in good qualitative agreement with the experimental data, except for intermediate subjects. The spearman rank correlations between target activation value and recognition time was significant for beginner subjects (r_s (9) = .65, $p < .05$), and for advanced (r_s (9) = .83 $p < .02$), but was no significant for the intermediates ($r_s = 0$).

Conclusion

The purpose of this experiment was to investigate the relationship readers with different levels of prior knowledge constructed between procedural text elements. It was assumed that the difference in prior knowledge organization of beginner, intermediate and advanced subjects were mainly caused by differences in the relationships among the goal, the actions, and the outcome, and that these relationships, reflecting organization of knowledge in memory, determined the reading times and the retrieval of information. Our results support this assumption.

The analysis of the primed recognition results showed that for beginners, the target recognition time varied with the surface distance between the prime and the target, whereas for the advanced and intermediate subjects, the outcome was always faster recognized than the actions. This result suggests that the beginners did not establish relation between the goal and the outcome during reading, and that for intermediates and advanced subjects, the outcome was more available in memory than the actions. Consistent with our main hypothesis, the prior knowledge organization of the beginner, intermediate and advanced subjects differed in the relationship they established among the goal, the necessary actions to attain the goal, and the obtained outcome.

However, contrary to our expectations, the beginners recognized true targets faster than the two other groups, the mean number of errors being equal for the three groups. Our interpretation is that the answers of the beginners were mainly based upon the surface features of the text (which was sufficient for these simple texts), whereas answers of both the intermediate and the advanced subjects were based on a deeper conceptual understanding.

Finally, we demonstrated that the Construction-Integration model proposed by Kintsch (1998) can be used to test hypotheses concerning the effect of prior knowledge structure on the elaboration of an episodic mental representation and on retrieval.

To conclude, understanding the interaction among prior knowledge structures, text features (Kintsch, 1994) or text structures (Caillies & al., 1997), and comprehension measures (McNamara, Kintsch, Songer & Kintsch, 1996; McNamara and Kintsch, 1996) is fundamental for a theoretical account of text comprehension. The Construction-Integration model proposed by Kintsch (1988,

1998) can provide a framework to approach these interactions.

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