Prior knowledge and interactive overview structure effects on cognitive load, disorientation and learning

Franck Amadieu, University of Toulouse-Le Mirail, France
Tamara van Gog, Open University of the Netherlands, Netherlands
Fred Paas Gog, Open University of the Netherlands, Netherlands
Andre Tricot, Toulouse University for Teachers' Education, France
Claudette Mariné, University of Toulouse-Le Mirail, France

Abstract
This study investigated the effects of the structure of an interactive conceptual map and the level of learner's prior knowledge on their disorientation, cognitive load, and learning. The content to which the interactive conceptual map gave access was a text on the life cycle of a retrograde virus (HIV). Two types of map structures were designed: (a) low level of structure; a network that displayed the main concepts in an unstructured fashion, and (b) high level of structure; a hierarchical structure that displayed the same concepts according to categories of the domain. Eye movements were recorded during the first minutes of task performance. The results revealed that the hierarchical structure supported a better knowledge gain of factual knowledge and conceptual knowledge. But the hierarchical structure entailed higher conceptual learning (comprehension of relationship between concepts) only for low prior knowledge learners, whereas it entailed better factual knowledge learning (information specific to a concept - factual knowledge) only for high prior knowledge learners from the hierarchy focusing on details information. The results showed also for all participants an important cognitive load (i.e. disorientation and complexity perceived) entailed by the network structure compared to the hierarchical structure. Analyses of the eye movement data showed that the average fixation duration was higher for the hierarchical compared to the network structure. Interestingly, correlation analyses revealed that the average fixation duration was negatively correlated with the mental effort ratings and disorientation scores, but only within the network structure condition.

Summary
Hypertexts are informational electronic devices providing a non-linear organisation allowing and requiring the user makes his own sequence of the information (Conklin, 1987). The requirements of hypertexts using would entail cognitive overload and disorientation (Conklin, 1987 ; Niederhauser, Reynolds, Salmen, & Skolmoski, 2000) hindering an effective learning activity. However, few empirical studies assed disorientation or cognitive load, and fewer studies showed a negative effect of the disorientation on performance (Ahuja & Webster, 2001 ; Otter & Johnson, 2000).

Actually, authors argue or expect that high prior knowledge learners would benefit more from a flexible hypertext (e.g. network structure) whereas low prior knowledge learners would benefit more from a « well organised hypertext » as a hierarchical structure (e.g. Chen, Fan, & Macredie, 2006). However looking at the empirical literature, domain novices seem to reach better performance if a linear or hierarchical structure is provided, whereas experts do not benefit from any type of structure (Calisir & Gurel, 2003 ; Lee & Lee, 1991 ; Patel, Drury, & Shalin, 1998; Recker & Pirolli, 1995; Shin, Schallert, & Savenye, 1994).

Our study was conducted within the theoretical framework of the cognitive load theory (Paas & Van Merriënboer, 1994 ; Sweller, Van Merrienboer, & Paas, 1998). We argue that a learner built a comprehension of the hypertext content establishing coherence between concepts between the different nodes. To reach deep comprehension, learners have to mobilize important resources to run processes like decision making about the next node to consult, the construction of semantic link between concept,… Hence, a low prior knowledge learner will encounter high extraneous cognitive load. The learning performance will be hindered because a few resources will be allocated for the germane cognitive load.

Introducing an overview displaying a hierarchical structure of the hypertext, low prior knowledge learners should build a semantic representation based on the overview structure because the overview drives the attention on the main concepts and their semantic relationships.

Concerning the effects of high prior knowledge, knowledge structure supports learning in non-linear hypertext (i.e. network) freeing resources in working memory and providing resources to run deep processing. On one hand, prior knowledge should reduce intrinsic cognitive load and thus free resources to run processes not useful for learning (i.e. extraneous cognitive load), and on the other hand, prior knowledge should support processing for establishing coherence between concept. High prior knowledge learners would activate prior knowledge to run elaborative inferences based on knowledge base in order to establish coherence, and hence, the germane cognitive load would be increased.

Method

The learning task consisted in studying a lesson on a computer dealing with the life cycle of the HIV (i.e. the infectiousness process of a cell by the HIV). Two types of lesson were compared based on the structure of an interactive conceptual map: (a) a hierarchical structure (i.e. main part of the lesson are distinguished by categories and the sequence of the process was respected), (b) a network structure (i.e. the concepts of the lesson were organized “randomly”). Twenty-four individuals (age M = 32.3, SD = 8.05; 15 females and 9 males) volunteered for participating. A pre-test assessed prior knowledge in the cell biology domain. In order to increase the difference between low and prior knowledge, the high prior knowledge learners studied before the learning phase a life cycle of a virus closed to the HIV giving them a macrostructure of the cycle life of the retroviruses.

Learning performances were assessed computing differences between post-test scores (questions) and pre-test scores on the retrovirus’ life cycle. Two types of knowledge were distinguished: (a) the factual knowledge (i.e. about information explicitly mentioned into a text section) and (b) conceptual knowledge (i.e. about implicit information understandable making inferences on relationships between different information between different text sections). For each type of questions (factual and conceptual) mental effort invested to answer the questions was measured thanks to a subjective scale in nine points.

Different scales were used to measure the cognitive load involved during the learning task: mental effort, perceived complexity of the lesson, disorientation (5 items), mental effort to process the map. A measure of eye movements was added to assess cognitive load and processes linked to the conceptual map processing.

Results

No significant differences were observed on the ratings mental effort scale, but the level of perceived complexity was higher for the network structure for both levels of prior knowledge. Average disorientation ratings were also lower in the hierarchical structure compared to the network structure, but the effect was only significant for the low prior knowledge learners. Analyses were conducted on the average fixation duration on the conceptual map (hierarchical vs. network) recorded the first minutes of the learning phase. The average fixation duration was higher for the hierarchical compared to the network structure. Interestingly, correlation analyses revealed that the average fixation duration was negatively correlated with the mental effort ratings and disorientation scores, but only within the network structure condition.

Concerning performance, for the factual knowledge scores, only high prior knowledge group benefited more from the hierarchical structure than the network structure. But for the

conceptual knowledge scores the reverse result was observed showing that the low prior knowledge group tended to benefit more from the hierarchical structure whereas the high prior knowledge learners did not benefited from any type of structure. The ratings of mental effort invested to answer all questions (factual and conceptual) were lower in the hierarchical structure condition, but only for the lower prior knowledge learners.

In conclusion, the results corroborated that a hierarchical structure of an interactive conceptual map support higher deep learning for low prior knowledge learners but the results showed that high prior knowledge learners having a mental representation consistent with the conceptual map structure, may benefit more from the hierarchy focusing on details information (factual knowledge). Cognitive load investigations highlighted globally a higher cognitive requirement of a network structure. The average fixation duration appeared as a good measure of cognitive load linked to disorientation.