A Longitudinal Perspective on the Relationship between Hypermedia Structure and Comprehension

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Abstract: This paper presents results from an experiment in which fourteen subjects browsed one of two versions of an educational hypermedia system presenting the functioning of the Internet during four consecutive sessions. Schematics produced by subjects to elicit their understanding of how the Internet works were analyzed to evaluate the role of their growing system and domain expertise on the influence of hypermedia structure on acquired knowledge organization. Although no significant effect of hypermedia structure on schematic configuration could be identified, subjects tended to use the same organizing principle to structure their schematics over the course of the four sessions.

Introduction

How hypermedia structure influences the organization of knowledge acquired by users is a question that has been thoroughly investigated in the literature over the years (Rouet, 1992; Tricot, 1997). Two key findings in this area are that (1) subjects integrate both structural and semantic cues presented by the system to discern information organization or "shape" (Dillon, 2000; Dillon & Vaughan, 1997; Dillon & Schaap, 1996), and that (2) the influence of structural cues is mediated by navigation, as hypermedia structure partly determines navigation pathways, which in turn impact understanding (Fastrez, 2005).

Prior knowledge (domain knowledge and system expertise) seems to affect how users learn with hypermedia (Mitchell et al., 2005). The question this paper aims at answering is how the influence of hypermedia structure on comprehension evolves over time, i.e. as the users' domain knowledge and system expertise grow. On the one hand, as users become system experts, they are able to take greater advantage of the complexities of hypermedia structure than novice users (who are known to perform better with linear, more restricted structure). On the other hand, as users develop domain knowledge, their deep understanding of the subject matter (and the semantic relationships between information chunks) allows them to impose structure on the hypermedia content (whereas novices who lack that kind of structure may feel compelled to conform to the structure provided by the system).

In this paper, I present results from a recent experiment that involved the collection of longitudinal data to address this question.

Methods

The experiment involved two versions of HyperDoc, an educational hypermedia system presenting "how the Internet works" from different perspectives, initially developed for a previous research program (Fastrez, 2005).

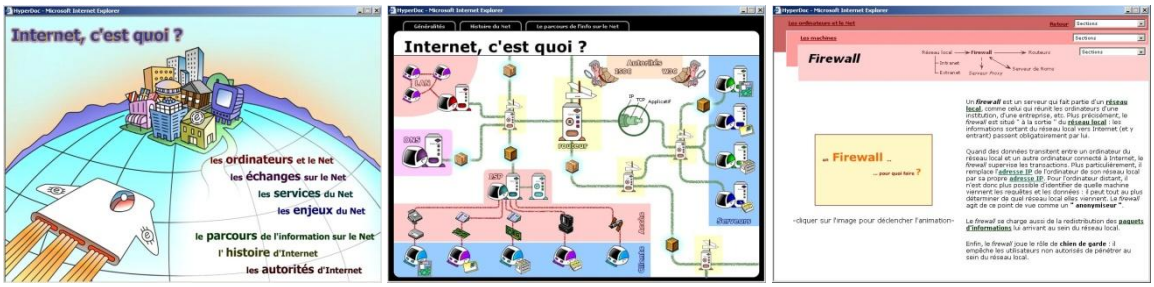


Figure 1: HyperDoc Screenshots (left to right: Version A Homepage, Version B Homepage, Sample Page).

The two version of HyperDoc share the same textual contents, illustrations and animation, and differ in terms of their structure (i.e. how their nodes are grouped into sections and subsections). Version A is organized thematically, with its main section corresponding to the following themes: hardware, software and protocols, services, social usage, history and institutions. Version B is organized geographically, around a simplified representation of a network topology, connecting clients with servers, routers, LANs, etc. In both versions, each section contains sub-sections, and each sub-section contains pages. The two organizational principles of HyperDoc A and B are especially apparent in their respective homepages (see Figure 1).

Participants

Fourteen first-year university students majoring in communication, political science or economics were recruited to participate in the experiment. Subjects were assigned to one of the two conditions defined by which version of HyperDoc (A or B) they were invited to use (see below). The gender ratio was identical in the two conditions (5 female subjects to 2 male subjects in each condition). Participants received a 10 € gift certificate for each session they participated in.

Task

Over a period of one month, each subject participated in four consecutive sessions consisting in a 30-minute browsing task, the goal of which was to answer the question: "How does the Internet work?". Subjects in condition A browsed HyperDoc A, and subjects in condition B browsed HyperDoc B. Subjects were allowed to take notes using paper and a pen during the task. The task was followed by a post-test, where participants were asked to answer the question both verbally and by drawing a schematic.

In this paper, I present and discuss the analysis of the schematics produced by subjects as part of the experiment. This analysis relies both on the schematics themselves and on the verbal commentaries subjects formulated on them, which were used to disambiguate their meaning in case of doubt. The analysis focuses on the global structural features of the schematics produced by the participants in both conditions, and their evolution as subjects gain domain knowledge and system expertise through their use of HyperDoc.

Questionnaire

Prior to the first session, subjects were asked to fill a questionnaire adapted from the Computer-Email-Web fluency scale (Bunz, 2004), in order to evaluate their prior experience with the Internet. The CEW fluency scale includes four components (computer fluency, email fluency, web browing fluency and web editing fluency) that each corresponds to a number of "I can…" assertions (such as "I can print a document" or "I can edit bookmarks"), which the respondent has to rate on a five-point Likert scale (from "very easily" to "not at all"). Each component corresponds to a score that averages those rating for a given subject. Our questionnaire complemented the CEW components with additional questions related to the respondents' frequency of use of email and the World Wide Web, as well as a few basic demographic questions (gender, year of birth, etc.).

In an attempt to classify the participants into novice and expert web users, a hierarchical cluster analysis was run on data from selected questions of our questionnaire: one question on the time span of their Internet use personal history, three questions related to their frequency of use of the World Wide Web, and their web browsing and web editing scores from the CEW fluency scale. Similarity scores were computed based on these data using the Gower similarity coefficient for mixed data types (Gower, 1971). The complete linkage method was used to cluster the cases based on these scores.

Three clusters were identified: a group of three subjects with limited web experience (lower usage and lower CEW scores), a group of frequent web users with higher CEW scores, and a group of less frequent web users with similar CEW scores. However, this classification failed to yield any significant result in terms of observable differences in the schematics produced by the subjects. A possible explanation lies in the comparative nature of the measures used to categorize subjects, as similarity scores only provided an assessment of the subjects' experience relative to one another, possibly dissimulating a relative homogeneity in terms of web experience in our sample. Additionally, this homogeneity may have been accentuated by the fact that the CEW fluency scale represents a basic fluency measure, as it does not include sophisticated items (Bunz, 2004), which may have caused subjects to be categorized differently, had they been part of the scale. As the identification of the three clusters mentioned above did not yield any significant results in the analysis presented hereafter, this classification will not be further discussed in this paper.

Results and Discussion

The schematics produced by the participants can be categorized based on the type of generic frame that structures them, namely: map-like drawings, time sequences, diagrams, and hierarchical outlines (corresponding to a discourse schema, not a referential schema). To avoid all ambiguity in the categorization, each schematic was coded as an array of embedded patterns, each pattern involving one or several of the following four basic semantic relationships: *space* (items in the pattern are laid out to reflect their spatial or topological relationships), *time* (items are linked to represent consecution), *entailment* (items are linked to reflect that A entails B, i.e that if A is true than B is true) and *category* (item layout represents a category and its members).

Our analysis will focus on the type of top-level patterns used by subjects to structure their whole schematics. Figure 2 shows a schematic (produced by A.L. during her third session) whose top-level pattern is spatial, and contains two additional sub-patterns that are categorical (shaded areas were added on figure 2 to highlight these sub-patterns).

Eight combinations of the aforementioned relationships into top-level patterns were observed in the schematics. These eight combinations were grouped into the four frame types we mentioned earlier: *diagrams*

(top-level patterns involving entailment, or category and entailment), *outlines* (top-level patterns involving category), *maps* (top-level patterns involving space, category and space, or space, time and entailment) and *sequences* (top-level patterns involving time, or time and entailment). Each pattern included in a schematic was thus coded according to the semantic relationships it involved, which allowed us to categorize the schematics based on their frame (i.e. top-level pattern) type.

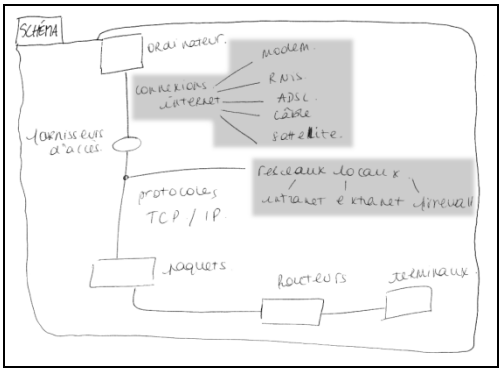


Figure 2. A sample schematic, with an overall spatial pattern, and two category sub-patterns (in shaded areas).

Central to our analysis is the fact that some of these frame types match the metaphors underlying the two versions of HyperDoc: respectively, diagrams and outlines can be paired with HyperDoc A, and maps with HyperDoc B. Hence, one should expect to find subjects relying more often on the frame types that are in line with the version of HyperDoc they browsed.

Schematic Frame Type per Condition

Table 1 shows the respective distributions of frame types in the two conditions, for all four sessions (amounting to 56 schematics, i.e. 4 for each of the 14 subjects). Contrary to our expectations, these distributions did not differ significantly ($\chi^2 = 3.84$; $p = 0.279$).

Table 1: Schematic Frame Types per Condition

	Condition A	Condition B	Total
Outlines	11	7	20
Diagrams	2	1	21
Maps	7	14	21
Sequences	8	6	20
Total	28	28	56

A closer look at this table reveals that the main difference between the two distributions corresponds to the number of maps produced by subjects of both conditions, with twice as many in condition B as in condition A. Subjects in condition B seem to have a slight tendency to structure their schematics as maps more often than subjects from condition A. An additional test setting maps against all other frame types yielded results on the edge of statistical significance ($\chi^2 = 3.73$; $p = 0.0533$).

Frame Type Evolution over Time

The next step in our analysis was to determine whether subjects used different frame types to structure their schematic as they went through the four sessions of the experiment. Table 2 summarizes the results, and categorizes subjects according to the sequence of transitions between schematics they went though (S_i stands for the schematic of the i^{th} session).

Table 2: Transitions between Frame Types over the Four Sessions

	Condition A	Condition B	Total
Constant Frame ($S_1=S_2=S_3=S_4$)	3	6	9
Temporary Change ($S_1=S_2=S_4\neq S_3$ or $S_1=S_3=S_4\neq S_2$)	1	1	2
Back and Forth Switch ($S_1=S_3\neq S_2=S_4$)	1	0	1
Definite Change ($S_1\neq S_2=S_3=S_4$)	2	0	2
Total	7	7	14

A majority of eleven subjects (9+2) used the same frame type to structure their initial and final schematics. Two of them changed once over the course of their four sessions, and then came back to their initial choice. Nine of them used the same frame type all four times. The remaining three subjects used different frames at start and at finish, either going back and forth between two frame types, or changing once and for all after the first session. The ratio between eleven 'constant' subjects and three 'changing' subjects is significantly different from a hypothetical even distribution ($\chi^2 = 4.57$; $p > 0.05$). Hence, it appears that subjects tended to stick with the frame they first picked in a majority of cases. This trend was stronger in condition B (i.e. subjects in this condition tended to change frames less often, and always got back to their original choice) than it was in condition A. However, the difference between conditions fell short of being statistically significant ($\chi^2 = 3.82$; $p = 0.0507$).

The last step in our analysis inventories the number of final schematics (produced during each subject's fourth session) that drew on frame types matching the version of HyperDoc used by the subject. As mentioned above, compatible frames are diagrams and outlines for HyperDoc A, and maps for HyperDoc B. Table 3 distinguishes between final compatible and incompatible frames that were identical to or different from the frame used in the subject's initial schematic, in order to determine whether the subjects who changed frames did it to conform to the way the system they browsed was structured. Since two subjects out of tree changed for a frame that wasn't compatible with the version of HyperDoc they browsed, one cannot conclude that subjects changed the way they framed their schematics to make them compatible with the overall organization of the hyperdocument they used.

Table 3: Final Schematic Frame Compatibility per Subject Type

	Compatible	Incompatible	Total
Constant Subjects	6	5	11
Changing Subjects	1	2	3
Total	7	7	14

Conclusions and Future Work

The results presented above show that HyperDoc's organizing principles did not have any significant effect on the overall configuration of the schematic representations produced by our subjects (except for the slightly more frequent use of maps by subjects in condition B). Moreover, the top-level patterns used by subjects to structure their schematics were largely stable in time (at least in condition B), regardless of the growing expertise of participants on both the system and its contents.

Our analysis focused on the influence of hypermedia structure on comprehension at a global level. Further analyses of the same data will investigate into the possible influence of more local structural features of HyperDoc on acquired knowledge organization, and the evolution of this influence over time. Also, the results presented in this paper need to be ultimately complemented by the analysis of the verbal answers given by subjects to the task question.

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