As a result of our beta testing, we developed five user interfaces for the first CD-ROM and discovered that improving user interfaces is a continual process as the technology for future CD-ROMs offers graphical interfaces, multi-tasking, and smarter software programs.

Acknowledgments

Reference

William Horton, *Designing and Writing Online Documentation* (John Wiley and Sons: New York, NY, 1990).

Hypertext: A New Tool and Its Effect on Audience Comprehension©

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We examine comprehension research that suggests readers must have some degree of familiarity with a document's topic or structure to instantiate appropriate schemata. This research creates questions about the comprehensibility of hypertext documents. We conclude that research must be conducted in hypertext environments to assess the applicability of reading strategies, specifically those of schemata, in hypertext documents.

Hypertext, a new tool for delivering technical information to different audiences for different purposes, generally refers to electronic documents in which information is arranged and accessed in a nonlinear fashion. Nonetheless, when people read words and sentences, they do so in a somewhat linear fashion and comprehend the ideas in a hierarchical fashion. For years, technical communicators have relied on research from a variety of disciplines, research investigating paper and electronic documents that have been arranged in a linear fashion due to the limitations of the media. Not only have these documents been linear, but they have been designed for readers and users who generally process information hierarchically (1, 2). If we are to effectively deliver information in hypertext documents, we must question whether and under what conditions this new tool can effectively meet its audience's processing needs.

This article briefly examines reading models and then focuses on research on prior knowledge and schemata that suggests that readers must have some degree of familiarity with the topic and the structure of a document to be able to instantiate an appropriate schema with which to assimilate new information. Further, using this research base, we discuss the hypertext environment and question its comprehensibility. Finally, we cite the need for more research on hypertext to assess established comprehension principles developed from the mass of reading research.

Reading models

Many models of reading and comprehension acknowledge the influence of the reader's pre-existing knowledge on the reading process. It is interesting to note that all reading models attempt to represent the process of reading and comprehension as one of imposing order on incoming stimuli or one of building structure (3–8). Bottom-up models suggest that readers work from words to long term memory; top down models suggest that readers work from long term memory to individual words in the text; and interactive models suggest that readers use a mix of bottom up and top down processes. Kintsch and van Dijk assert that comprehension follows the reading process and entails [1] selecting a set of propositions to hold in short-term memory (STM), [2] processing a second set of propositions, [3] attempting to link the two proposition sets, [4] accessing long-term memory (LTM) to link the propositions if linking in STM fails, and [5] creating inferential links if necessary (6). The linkages formed in steps three through five are critical if readers are to comprehend and apply the information they take in during reading.

More recent comprehension models represent the processes of reading and comprehension as a set of procedures or productions akin to a structured computer program (9–11). The "if-then" rules can operate on information represented in the words and phrases in a text, the low- and high-level semantic content of a text, or the situation described in a text. These surface, propositional, and situational elements of a text interact in readers' memory representations and influence comprehension (12).

Prior knowledge and schema theory

The reading models discussed above maintain that readers' knowledge will interact with their comprehension processes. Readers' prior knowledge structures should facilitate readers in selecting text based information to store in memory, in linking new information with old information already present in memory, and in providing ideational anchors (13–15). These knowledge structures are often called schemata—abstract scaffolds with slots or placeholders that can be instantiated with specific bits of information. A general definition of schemata states that readers' schemata are equivalent to their expectations: what readers expect from a text will influence what they take in and retain from a text, how they interpret the text, and how they organize that information in memory. Piaget hypothesized that meaning occurs when the learner assimilates new information into an existing schema (16). Meaning does not appear to occur unless one of three possibilities exists: [1] the new information fits an existing schema; [2] the existing schema framework can be altered to contain the new information, or [3] a new schema can be built to accommodate the information (17).

According to schema theory, individuals build schemata based on knowledge they have acquired in the past. In particular, researchers have looked at how content and structure schemata based on prior knowledge or culture affect text comprehension.

Content schemata

Content schemata stem from readers' knowledge about a given topic. They help readers infer implicit relationships, acquire new information, and guide interpretation of text based information. Studies of content schemata have found that readers face problems when they call up an inappropriate schema, attempt to instantiate information into an inappropriate schema, or allow information from an inappropriate schema to intrude into their text comprehension. Most studies of content schemata focus on prior knowledge schemata while a few focus on culturally based schemata.

Researchers of schemata based on prior knowledge have generally examined the effects of strong versus weak or no schemata. Pearson, Hansen, and Gordon investigated readers who possessed strong or weak schemata for a topic and concluded that readers with strong schemata were more able to infer implicit relationships (18). Recht and Leslie found that strong prior knowledge overrode text based information and that when prior knowledge was compatible with the text, there was no facilitatory effect (19). Anderson, Reynolds, Schallert, and Goetz found that subjects injected more schema based information into a passage for which they had strong prior knowledge (20). Over 80% of their subjects were unaware of an alternate interpretation of ambiguous passages, indicating that the readers' schemata activated at a high enough level to eliminate consideration of other interpretations. Lipson found that readers familiar with textual information were better at acquiring totally new information than correcting inaccurate old information (21). Further, subjects with no prior knowledge performed better than subjects with inappropriate prior knowledge. Alvermann, Smith, and Readence found the comprehension of readers who had activated compatible prior knowledge before reading to be quite similar to that of readers who had not activated prior knowledge; however, incompatible prior knowledge interfered with the reader's comprehension of the correct information in the text (22).

Many researchers have noted that content schemata based on cultural knowledge also significantly influences comprehension. Steffensen, Joag-Dev, and Anderson compared the performance of readers from different countries (India, U. S.) and found a significant interaction of nationality and passage with each cultural group performing best (recalling more idea units and reading more quickly) with a passage from its own culture (23). When reading passages based on other cultures, each cultural group made more errors in elaborating idea units and constructed inappropriate schemata based on content schemata from its own culture. Lipson, defining culture in terms of religious affiliation (Catholic, Jewish), found that subjects took less time to read a culturally familiar passage and recalled more correct information and more explicit and inferred information from the culturally familiar passage (24). Reynolds, Taylor, Steffensen, Shirey, and Anderson examined the effect of race (black, white) and residence (urban, rural) on content schemata and found that readers interpreted passages based on their own cultural schemata (schemata that were intrusive for those with an inappropriate cultural schemata) (25).

Readers' content schemata based on strong prior knowledge or cultural influences have been shown to facilitate comprehension when the schemata are compatible with text and to impede comprehension when they are incompatible with text. In addition to content schemata, readers often approach text with preexisting schemata for a document's structure.

Structure schemata

Structure schemata stem from a reader's knowledge about text structure and, like content schemata, may be based on prior knowledge or cultural background. Structure schemata have been shown to assist recall, improve comprehension, and facilitate the identification of document coherence; further, they automatically activate themselves.

Brooks and Dansereau examined the effectiveness of [1] training students to use structure schemata as an aid in processing text and [2] using structure schemata as an aid in organizing text (26). Generally speaking, teaching the use of structure schema theory and organizing text according to structure schema theory assisted recall. Roller found that prior knowledge about content and structure influenced readers differently, depending upon their goal (27). While content schemata significantly affected the readers' perceptions of the importance of information, structure schemata significantly affected readers' summaries of passages. Finally, Olhausen and Roller examined the integration of structure and content schemata (28). Results indicated that when readers could use content schemata, they did not make full use of structure schemata. Further, readers tended to use their structure schemata in an automatic, unconscious way, and in a different way on difficult passages—they attempted to use structure schemata whether it was possible or not. The findings suggest that, with well structured text (containing both content and structure schema based information), readers use content schemata more consciously than structure schemata.

The effects of structure schemata can also be seen in studies of cultural schemata. McClure, Mason, and Williams investigated the culture based structure schema that readers develop for the sequence of events within stories (29). They found that different cultural groups used different strategies for making the narrative coherent and for choosing initial and final sentences in stories. Readers who lacked the schema used in a given story exhibited poorer comprehension because of the mismatch between the reader's and the story's structure schemata.

In addition, we know that readers who possess strong structural knowledge perform better with well structured texts than with unstructured texts, while readers without strong structural knowledge perform poorly with both structured and unstructured texts (30). Research has shown that readers of poorly structured hard copy and on-line text show increased reading times for topic sentences and reduced overall recall; however, in some instances clear overviews of the text's topics improve the recall of even unstructured texts (31, 32). We also know that readers who can rely on an author's structure and signaling of it demonstrate superior performance (33, 34). We further know that readers who cannot bring their structural knowledge to bear will exhibit recall patterns of poor comprehenders—a recall pattern that resembles a rote listing of equivalent information units (35, 36). The levels effect so critical to good reading, where superordinate and subordinate idea units are distinguished and hierarchically organized, will not appear.

Relationship of comprehension and schema to hypertext usability

While we would ideally like to draw strong conclusions about the comprehensibility of hypertext from the literature on reading models and schemata, we realize that research on known comprehension factors must be conducted in hypertext environments. However, the research reviewed here reveals that readers form linkages among textual information units based on information structures previously stored in LTM. When such information structures are compatible with a text, they facilitate a reader's interpretation and recall of text

based information; when they are incompatible, they supersede text based information.

Researchers in hypertext have recognized the similarity of readers' needs in traditional text and hypertext (37, 38). Smith, Weiss, and Ferguson indicate that readers of hypertext are susceptible to the same comprehension problems as readers of traditional text and that traditional text features that facilitate comprehension are apt to assist hypertext readers (38). Given the influence of readers' LTM and schemata on interpreting and linking information in linear documents, we must question how readers or users of hypertext identify relationships in the nonlinear hypertext environment, particularly when the information itself is not encyclopedic in nature.

While the needs and strategies of readers of linear and hypertext documents may be similar, hypertext documents cannot function similarly to structured texts due to their intentionally nonlinear nature. Some would maintain that hypertext documents do in fact possess internal linkages and relationships similar to those found in linear documents. But typical links between nodes, rather than being explicitly stated in relational words, are simply indicated by visual highlights. We must question whether readers comprehend the relationships signalled by such linkages.

Further, Gerhard Fischer et al. suggest that users of hypertext face the constant need to restructure information (39). We question whether readers can ever structure the information they take in, let alone continually restructure it. The goal of hypertext is to surpass the limitations of linear text; however, the major limitation that it surpasses—that of explicit structure and pre-established relationships— may actually create great difficulties for users. While the reading literature would suggest that readers rely on structure or content schemata to facilitate comprehension of poorly structured documents, readers of hypertext have no structure schemata to facilitate comprehension of the relationships between units of information. Whether hypertext readers may rely solely on content schemata to effectively facilitate comprehension remains to be seen. It is questionable how a user who is unfamiliar with the content base of a given hypertext document (and therefore lacking appropriate content schemata) would perform.

To provide guidelines that will assist the technical writer in designing effective hypertext documents, developers critically need research that investigates how and whether users of hypertext identify logical connections in hypertext documents and whether their comprehension reflects an understanding of superordinate and subordinate relationships. Furthermore, such research must be conducted with a variety of users who possess strong and weak content schemata and with dependent measures that actually reflect comprehension. When such research has been conducted, we will know whether our view of reading strategies, stemming from research studies of linear documents, accurately represents a reader's behavior with and comprehension of hypertext documents. And we will know whether we can extend document design guidelines currently based on that research in this new direction.

References

1.   G. McKoon, "Organization of Information in Text Memory," _J. Verbal Learn. and Verbal Behav._ **16**: 246-260, 1977.

2.   T. van Dijk and W. Kintsch, _Strategies of Discourse Comprehension_ (Academic Press: New York, 1983).

3. M. A. Gernsbacher, D. J. Hargreaves, and M. Beeman, "Building and Accessing Clausal Representations: The Advantage of First Mention Versus the Advantage of Clause Recency," *J. Mem. Lang.* **28**: 735–755, 1989.

4. K. S. Goodman, "Reading: A Psycholinguistic Guessing Game," in H. Singer and R. Ruddell (Eds.), *Theoretical Models and Processes of Reading*, 2nd Ed. (International Reading Association: Newark, DE, 1976).

5. P. G. Gough, "Information Processing Models: One Second of Reading," in Kavanaugh and Mattingly (Eds.), *Language by Ear and by Eye* (MIT Press, 331–358, 1972).

6. W. A. Kintsch and T. A. van Dijk, "Toward a Model of Text Comprehension and Production," *Psychol. Rev.* **85**: 363–394, 1978.

7. B. J. F. Meyer, "Text Dimensions and Cognitive Processing," in H. Mandl, N. L. Stein, and T. Trabasso (Eds.), *Learning and Comprehension of Text* (Lawrence Earlbaum Associates: Hillsdale, NJ, 3–50, 1984).

8. K. E. Stanovich. "Toward an Interactive-Compensatory Model of Individual Differences in the Development of Reading Fluency," *Read. Res. Quart.* **16** (1): 32–71, 1980.

9. D. E. Kieras and S. Bovair, "The Acquisition of Procedures from Text: A Production-System Analysis of Transfer of Training," *J. Mem. Lang.* **25**: 507–524, 1986.

10. W. Kintsch, "The Use of Knowledge in Discourse Processing: A Construction-Integration Model," *Psychol. Rev.* **95**: 163–182, 1988.

11. W. A. Kintsch, D. Welsch, F. Schmalhofer, and S. Zimny, "Sentence Memory: A Theoretical Analysis, *J. Mem. Lang.* **29**: 133–159, 1990.

12. A. J. Sanford and S. C. Garrod, *Understanding Written Language: Explorations of Comprehension Beyond the Sentence* (John Wiley and Sons: New York, 1981).

13. D. D. Ausubel, *Educational Psychology: A Cognitive View* (Holt, Rinehart and Winston: New York, 1968).

14. P. P. Afflerbach. "The Influence of Prior Knowledge on Expert Readers' Main Idea Construction Strategies," *Read. Res. Quart.* **25** (1): 31–46, 1990.

15. R. Fincher-Kiefer, T. A. Post, T. R., Greene, and J. F. Voss, "On the Role of Prior Knowledge and Task Demands in the Processing of Text," *J. Mem. Lang.* **27**: 416–428, 1988.

16. A. T. Prince and D. S. Mancus, "Enriching Comprehension: A Schema Altered Basal Reading Lesson," *Read. Res. Instr.* **27** (1): 45–54, 1987.

17. P. Whitney, "Psychological Theories of Elaborative Inferences: Implication for Schema-Theoretic Views of Comprehension," *Read. Res. Quart.* **22** (3): 299–310, 1987.

18. P. D. Pearson, J. Hansen, and C. Gordon, "The Effect of Background Knowledge on Young Children's Comprehension of Explicit and Implicit Information," *J. Read. Behav.* **11** (3): 201–209, 1979.

19. D. R. Recht and L. Leslie, "Effect of Prior Knowledge on Good and Poor Readers' Memory of Text," *J. Exper. Psychol.* **80** (1): 16–20, 1988.

20. R. C. Anderson, R. E. Reynolds, D. L. Schallert, and E. T. Goetz, "Frameworks for Comprehending Discourse," *Amer. Ed. Res. J.* **14** (4): 367–381, 1977.

21. M. Y. Lipson, "Learning New Information from Text: The Role of Prior Knowledge and Reading Ability," *J. Read. Behav.* **14** (3): 243–261, (1982).

22. D. E. Alvermann, L. C. Smith, and J. E. Readence, "Prior Knowledge Activation and the Comprehension of Compatible and Incompatible Text," *Read. Res. Quart.* **20** (4): 420–435, 1985.

23. M. S. Steffensen, C. Joag-Dev, and R. C. Anderson, "A Cross-Cultural Perspective on Reading Comprehension," *Read. Res. Quart.* **15** (1): 10–29, 1979.

24. M. Y. Lipson, "The Influence of Religious Affiliation on Children's Memory for Text Information," *Read. Res. Quart.* **18** (4): 448–457, 1983.

25. R. E. Reynolds, M. A. Taylor, M. S. Steffensen, L. L. Shirey, and R. C. Anderson, "Cultural Schemata and Reading Comprehension," *Read. Res. Quart.* **17** (3): 353–366, 1982.

26. L. W. Brooks and D. F. Dansereau, "Effects of Structural Schema Training and Text Organization on Expository Prose Processing," *J. Ed. Psychol.* **75** (6): 811–820, 1983.

27. C. M. Roller, "The Effects of Reader- and Text- Based Factors on Writers' and Readers' Perceptions of the Importance of Information in Expository Prose," *Read. Res. Quart.* **20** (4): 438–456, 1985.

28. M. M. Olhausen and C. M. Roller, "The Operation of Text Structure and Content Schemata in Isolation and in Interaction," *Read. Res. Quart.* **23** (1): 70–87, 1988.

29. E. McClure, J. Mason, and J. Williams, "Sociocultural Variables in Children's Sequencing of Stories," *Discourse Proc.* **6**: 131–143, 1983.

30. B. M. Taylor and S. J. Samuels, "Children's Use of Text Structure in the Recall of Expository Material," *Amer. Ed. Res. J.* **20** (4): 517–528, 1983.

31. R. F. Lorch and E. P. Lorch. "Topic Structure Representation and Text Recall," *J. Ed. Psychol.* **77** (2): 137–148, 1985.

32. R. F. Lorch, E. P. Lorch, and R. D. Matthews, "On Line Processing of the Topic Structure of a Text," *J. Mem. Lang.* **24**: 350–362, 1985.

33. J. H. Spyridakis, "Signaling Effects: A Review of the Research," *J. Technical Writ. Comm.* **19** (3): 227–240, 1989.

34. J. H. Spyridakis, "Signaling Effects: Increased Content Retention and New Answers," *J. Tech. Writ. Comm.* **19** (4): 395–421, 1989.

35. M. Wenger, *Reader Performance as a Function of Document Demands* (Unpub. M. S. thesis, University of Washington, 1989).

36. M. J. Wenger and J. H. Spyridakis, "On the Interaction of Text Difficulty and Familiarity in the Performance of Skilled Technical Readers" (submitted for publication).

37. D. G. Hendry, *The Relationship Between Navigation and Comprehension in a Hypertext Environment* (Unpub. M. S. thesis, University of Guelph, 1989).

38. J. B. Smith, S. F. Weiss, and G. J. Ferguson, "A Hypertext Environment and Its Cognitive Basis," *Proc. ACM Hypertext '87 Conf.* (Chapel Hill, NC, 13–15 November, 195-214, 1987).

39. G. Fischer, W. P. Jones, W. Kintsch, A. C. Kay, R. H. Trigg, and S. A. Weyer, "A Critical Assessment of Hypertext Systems," *Proc. ACM CHI '88* (Washington D C, 15–19 May, 223–227, 1988).

Optical Storage Technology: A New Era©

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Optical technology continues to move forward. It promises to be more than a mass storage, archiving device. Once its data access time increases, it will receive greater acceptance from personal computer users. Then, the high-powered, instant access computers promised in the early days of the personal-computer revolution will be a reality. Mass data storage capacity was addressed by optical technology with the invention of the CD/ROM (compact disc/read-only memory) and WORM (write once, read many). But, CD/ROM and WORM left computer users unable to take advantage of optical technology if there was a need for mass storage and the flexibility to store and erase files numerous times. CD/ROM's data is prerecorded and unalterable, and once data is written to the disk, in the WORM environment, the stored data is unalterable. Magneto-Optical (MO) technology solved those problems. MO is a combination of CD/ROM and WORM technologies in a rewritable platform. It is impervious to magnetic fields, can store data for 10 years or more and is standard SCSI-interface. The capability to be replenished with removable cartridges, adds additional value to MO's standard data storage capacity of 600 megabytes to 1 gigabyte (1,000 megabytes). MO is the focus of this paper. However, to understand MO technology it is necessary to understand the basic principles of optical technology. Therefore, this paper will explain how optical technology works. It examines the three aspects of optical technology—-CD/ROM, WORM and MO. Some of the disadvantages associated with MO technology in relation to magnetic disk technology are discussed. The reader will find an overview of future optical technology.