Association for Information Systems

AIS Electronic Library (AISeL)

SIGHCI 2003 Proceedings

Special Interest Group on Human-Computer Interaction

2003

A Model Made of Paper: Clinicians Navigate the Electronic Health Record

Catherine Arnott Smith

Syracuse University, casmit07@syr.edu

A Model Made of Paper: Clinicians Navigate the Electronic Health Record

Catherine Arnott Smith
Syracuse University
casmit07@syr.edu

ABSTRACT

The electronic health record (EHR) is actually an aggregation of individual clinical documents. Medical records document not only the knowledge domains of clinical practice, but the work processes and practices that support these domains. Human-computer interaction is an important factor in EHR system success: researchers have argued that clinician readers consciously perceive the context of production, and integrate an understanding of the producer into their understanding of the data. In support, this paper reports findings of an information retrieval study using a simulated EHR containing deidentified clinical documents. Physician subjects verbally demonstrated use of a mental model of the paper medical record during their navigation of the system. Clinicians may actively apply a mental representation of their domain of practice—and actively refer to this paper-based knowledge base—when they access medical data. An understanding of the mental models that clinicians use would greatly inform our understanding of EHR systems.

Keywords

Clinical information systems; medical records; passage retrieval; mental models

INTRODUCTION

The electronic health record, or EHR, has constituted one of the great unattained goals of medical informatics since the early 1970s: the 'quest for the Holy Grail' (Gregory, Mattison, and Linde, 1995 p. 59; Nygren and Henriksson, 1992). Facilitating access to the medical record has historically been viewed as such a resource-consuming task that electronic medical record construction was the driving force behind early hospital information systems (Collen, 1987). And as early as 1975, researchers in medical informatics argued that "the psychological characteristics of the user should be taken into account in the design and implementation of medical information systems" (Herbst, 1989, p. 389). To understand the problem of clinical information retrieval in the context of an EHR, it is necessary to understand not only its users, but the nature of the data that comprise it.

The medical record is a feature of patient care as much as 3000 years old (Spiegel and Springer, 2001). Frisse (1992) has identified four principal ancestors of the modern medical record: (1) the case record collection of the 19th century, resembling "diaries or research notebooks"; (2) the bedside chart containing individual patients' vital signs and observations; (3) the physician order, used for workplace communication; and (4) the financial ledger, or record of physician charges and transactions. Today, still patient-centric, still resembling its ancestors, the typical record is still kept on paper. EHRs have penetrated only 5-10% of the U.S. market (Carpenter, 2002). Small wonder that one author has asked: "Is a user-friendly, secure and interactive electronic medical record a figment of the collective imaginations of overzealous techies?" (Thompson, 1996, p. 29). What has prevented attainment of this particular future? Morrissey (2001) blames the "best of breed" mentality prevalent in healthcare IT: "Healthcare applications were selected to satisfy a particular department rather than their ability to share and consolidate information with other applications and the healthcare system as a whole". Thus, the integration of data from applications that were best for different things has only reinforced and perpetuated a pre-existing lack of communication and disdain for standards.

The most fundamental function of the medical record is that throughout its development, in whatever medium, it always documents not only the knowledge domains of clinical practice, but the work processes and practices that support and maintain the operation of these domains. Sociologist Marc Berg (1996) wrote that the record "is part and parcel of the production of hierarchical relations, of the shaping of the doctor-patient encounter, of the processes that constitute the socialization of interns, and so forth" (p. 501). Rees pointed out that "the very possibility of understanding the record's entries is based on a shared, practical, and entitled understanding of common tasks, experiences, and expectations" (Atkinson and Heath, 1981, pp. 200-201). Whether digital or paper, the medical record encodes work processes and subprocesses.

The traditionally oriented medical record is organized around sources of medical data, such as patient encounters with the physician. For example, in the MARS (Medical Archival and Retrieval) System in use at the University of Pittsburgh Medical Center, the organizational scheme is traditional: unstructured free-text narratives are classed by one of 19 clinical report types, with the text providing a further account according to that central event. For example: a "Radiology Report" breaks down into components describing the procedure performed, clinical data associated with/generated by the procedure, and the final conclusions of the radiologist regarding the data. The EHR as "medical record" is actually an aggregation of individual clinical documents like this.

An EHR system thus needs to be understood as a document base rather than a database, "based primarily upon a store or collection of documents, rather than a store or collection of structured data" (Chen and Dhar, 1991, p. 406). Typical clinical tasks performed using EHR systems include the following (Laerum et al., 2001): Reviewing the patient's problems; seeking specific information from patient records; Following results over time; obtaining new results; and reviewing cohort data. Clinical information retrieval occurs in situations in which every second, clinically, counts, which makes human-computer interaction an important factor in EHR system success. Retrieval in this domain simply "can't be more time-consuming than reading from a conventional paper record" (Nygren and Henriksson, 1992, p. 1) or clinicians have no incentive to use, let alone rely upon, the system. An understanding of the mental models that clinicians use when they access information retrieval systems in medicine would greatly inform our understanding of the systems.

MENTAL MODELS

I use here Borgman's definition (1999): "a cognitive mechanism for representing and making inferences about a system or a problem which the user builds as he or she interacts with and learns about the system" (p. 436). Donald Norman stated early (1983) that a person's mental model "reflected his or her beliefs about the physical system, acquired either through observation, instruction, or inference" and furthermore that an individual's "beliefs about a system lead to expectations of the system's capabilities" (Norman, 1983). Kieras and Bovair (1984) early on found that imparting device model information to the user had strong effects on that user's ability to use the system; Fein, Olson and Olson (1993) followed on these findings to investigate a continuum of mental models at work in the use of a control panel. To support the model-understanding connection, some have blamed the "inadequacy" of mental models for users' inability to cope with system failures (Cardinale, 1991) and subjects' mental models have been found to interfere with learning when mapping from "print" (typewriter mental model) to "digital" (computer mental model) (Borgman, 1999, citing Douglas, 1983).

According to Borgman (1999), the bulk of research in the area of mental models and computers has related to text editors and calculators; see, for example, Halasz and Moran (1983). The body of IR research that has considered mental models has done so primarily in the service of training. Dimitroff (1992) focused on the relationship between mental models and users' outcomes in searching a bibliographic retrieval system and found that subjects whose models were most "complete" found significantly more items when searching. Borgman (1999), like Dimitroff, investigated the contribution of users' mental models to success in task performance using an IR system. She found that even subjects who were not trained in the use of mental models were able to develop such models without assistance, echoing the conclusions of Fein et al..

PASSAGE RETRIEVAL

The research reported in this paper was based in the theory of passage retrieval, a subset of corpus-based information retrieval: "the task of identifying and extracting fragments from large, or short but heterogeneous, full text documents" (Melucci, 1998). Passage retrieval is thought to enable more precise retrieval because it concentrates the reader's attention on those parts of the text that have a "high density" of relevant information, thus providing an "intuitive overview" of the knowledge base (Salton and Allan, 1993).

Can this be ascribed to a mental model? Eveland and Dunwoody (2000) proposed that hypermedia learners have their own model-building facilitated by the visual and ontological scaffolding provided by hypertext links. When the learner uses the scaffolding, "The structured representation acts as an intensional definition, in the particular vision of a world embedded in a structure." (Rossi Mori, Galeazzi, Consorti, and Bidgood, 1997).

The clinical documents that make up the EHR can be considered to be composed of passages, since they contain units of textual discourse such as sentences, paragraphs, and sections. Clinical documents are typically extremely short, and have unique and nonredundant text. However, clinical document section headings are more like database fields than the content summaries seen in passage retrieval research (for example, Hearst and Plaunt, 1993). These "section headings", "labels", or "segment labels", as they are variously called in the literature, serve as the means by which readers navigate the documents. Nygren, Johnson, and Henriksson (1992) identified three reading techniques of medical records: first, skipping over irrelevant sections; second, skimming sections identified as possibly relevant; and third, reading needed information carefully. Labels thus signal content to the reader, both denoting the structure and defining the domain of knowledge.

This paper reports findings of a clinical information retrieval study using a simulated EHR system with a document base of deidentified but authentic clinical documents. The purpose of the study was to assess the contribution of XML markup to improved retrieval of clinical documents. Subjects were assigned information retrieval tasks to which the document base provided the gold standard answer. The control group searched a flat file of ASCII full-text clinical documents; the treatment group could pose field-based queries enabled by XML markup of passages denoted by section headings. A side effect noted during the experiment was the demonstration by physician subjects that they incorporated a mental model - a model of the paper document base - into their own navigation of the simulated system.

METHODS

This experiment was conducted during April and May, 2002. One thousand clinical documents from the MARS system in place at the University of Pittsburgh Medical Center (UPMC) were randomly selected and automatically deidentified; that is, all individual identifying information was removed and replaced with pseudonymizing text. These 1000 documents were evenly distributed among the 8 most frequently occurring types found in a pilot study: radiology reports; progress notes; physician letters; operating room notes; history and physical notes; surgical pathology reports; discharge summaries; and emergency room visits. Subjects were 10 physicians (9 M, 1 F, ages 28-45) drawn from a convenience sample, experientially varying from a medical school graduate to attending faculty members. Results are also reported here from a pilot study involving 5 additional male physicians meeting the same criteria.

The simulated EHR was built with an open source XML database called Xindice. The simulation offered the same search capabilities as did MARS, but used a purposely simple Web-based browser interface. Subjects could use Boolean operators and partial string matching to search full-text XML documents, return a list of results, and display full-text documents for further browsing. A session log running behind the scenes captured user activity. A written log of subject comments was kept by the investigator during each search session. Subjects are referred to by number, for example, Subject Five = S5; Pilot Study Subject Six=PS6.

THE SEARCH EXPERIENCE

Comments about the Experiment

Several subjects were careful to make a distinction between the artificiality of their environment and the clinical setting the environment attempted to replicate. S5 used the phrase “in real life” while S6 told me what he would do if it wasn’t an experiment:

[There’s a] difference between the two searches—why? Have to figure out. In real life would go on and compare. (S5).

I would look at 49 – they have to be in here! (S6).

And S1 noted:

In real life, I probably wouldn’t be going through all these! (S1)

However, one subject did twice comment that the experiment was realistic:

That’s exactly how you would look for this sort of thing. (S8). ... They were Discharge Summaries and Consult Notes—just what I would have wanted! (S8).

About the Search Process

Comments spoke to the role of the searcher and to the searcher’s understanding of his or her role in interpreting the document. As S8 remarked rhetorically:

Am I a clinician or a research assistant?

And PS S3 achieved the same effect by stating firmly:

I’m not a neurologist!

Most subjects indicated by their comments that they knew likely locations for information:

If I could search ‘Past Medical History’, something would be structured ... (S6)

It’s probably going to be under ‘Social History’! (S8)

‘Adenocarcinoma’ would have to be in the ‘History’. (S4)

In my mind there’s an idea that this would go with ‘Procedure’ or ‘Techniques’. I was happy to click on ‘Procedure’ and try to search! (S5)

I expected it to be in ‘Hospital Course’ because it’s medicolegal. Anything that happens to the patient while they’re in the hospital is going to be in there! (S6)

I read ‘Techniques’ for ‘premedication’ – that’s where I would expect to see it. (S5).

Conversely, some information was *not* expected to be in particular locations; subjects were capable of expressing surprise:

‘Physical Exam’ – shouldn’t be there, but we don’t know! (S9)

The only other place to look would be the ‘History’ part, but there are only a couple of those (S3)

‘Substance abuse’ was not in ‘Social History’—that’s where it should be, but it’s not! (S6)

‘Pleural effusion’ should be in the ‘Reason’ part, not ‘Hospital Course!’ (S5)

Strange to find it there! I thought it would be under ‘Cytogenetics’, but it’s molecular genetics. (S5).

[“Why did you go straight to the ‘Description of Operation’ field?”] Because that’s where they’d deal with ‘resection’. It wasn’t where I expected it to be! (S10)

About the Documents

One common subject response was to verbally place themselves in the role of the document creator, sometimes recreating what they considered to be the thought processes of the document creator. S8 explained that the length of a clinical document related directly to medical billing, since "extensive documentation of history" (i.e., "No history of diabetes") enabled "upcoding" for a larger bill matching the longer dictation; or "some people just keep on going." Similarly:

Some people say 'Past Medical History', some people say 'Past Surgical History'. (S10).

But some subjects made guesses as to what kind of clinician dictated the note, apparently as part of their sense-making about the content:

I think a medical student wrote this! (PS S3)

A dermatologist probably didn't write this. They would have more accurate terminology! … An internist wrote this. Would have been easier if a dermatologist wrote it! (S4).

This is just my observation: Consultants say 'Impression' and primary care [physicians] say 'Plan!' (S8)

Two subjects verbally assumed the creator's role:

I'll just search for 'colon' because I'm not mentioning a normal guy's colon! (S8).

I just thought that if I were dictating a note…where would I put that information? (S7)

In two cases, the subjects attempted to second-guess the document author's diagnosis as part of their search strategy:

If I could remember the things that cause phlebitis, I could look those up! (S1)

Even though it says 'rectal', I consider this colon cancer! Rectal cancer is similar to colon cancer. (S12)

And two subjects verbally corrected the absent document creator:

I have used 'liver mass' in this situation – [the author of the document] should have used other words. (S6)

The word wouldn't be 'ileoscopy.' It would be 'ileostomy.' … The syntax is weird in the diagnosis. (S7).

This expressed itself in one case in a dialogue with the phantom author:

How dare you say 'degenerative joint disease' instead of 'arthritis?' Don't you know I'm going to be searching for this, you jerk? (S8)

DISCUSSION

Context is vitally important to communication of medical data. Whether an EHR is document-centric or data-centric, when it reflects clinical work processes, it becomes a working model of the clinical knowledge domain. As a result, Panko et al. (1999) have noted a drawback in constructing such systems via relational databases: "[T]he loss of both context and integrity when such elements are extracted and isolated from the original report" (p. 5). This context is "a knowledge base… composed of expert knowledge about the domain (medical application) and knowledge about documentation in the domain" (Poullet, Pinon, and Calabretto (1997), p. 120; italics mine).

Once the EHR is fully understood as a knowledge base, requiring context for accurate interpretation, the question then for systems developers becomes how best to represent that knowledge. Clinicians may actively apply their own representation of their domain of practice—actively refer to this paper-based knowledge base-- when they access medical data: "The data are transferred embedded in the significance-functions contributed by the conceptual frameworks of the relevant parties" (Kluge, 1996, p. 88). This framework is a filter that clinicians use to process the data they read. "In and of themselves, these data are not related", but the connections between the data points are the "information-space for the set of data" (p. 90). Or, as Essin puts it more succinctly, in his own Information Model: "Facts originate in events. Facts require context to be informative." (quoted in Royal College of General Practitioners, 1999).

Clinical information and work context are intimate and inseparable, and "The further information has to be able to circulate, the more work is required to disentangle the information from the context of its production" (Berg and Goorman, 1999, p. 52). Human readers of medical information interpret and reinterpret to assess the information "in the light of who generated it" (Berg and Goorman, 1999, p. 55), whether that generator be a human being or a machine. Readers consciously perceive the context of production, and integrate an understanding of the producer into their understanding of the data. I hope in future research to further explore the relationship between clinician readers and the mental models that document their clinical worlds.

REFERENCES

1. Atkinson, P., and Heath, C. (Eds.) (1981) *Medical work: Realities and routines*. Farnborough, England: Gower.
2. Berg, M. (1996) Practices of reading and writing: The constitutive role of the patient record in medical work. *Sociology of Health and Illness*, 18(4), 499-524.

3. Berg, M., and Bowker, G. (1997) The multiple bodies of the medical record: Toward a sociology of an artifact. *Sociological Quarterly, 38*(3), 513-537.
4. Berg, M., and Goorman, E. (1999) The contextual nature of medical information. *International Journal of Medical Informatics*, 56, 51-60.
5. Borgman, C.L. (1999) The user's mental model of an information retrieval system: An experiment on a prototype online catalog. *International Journal of Human-Computer Studies,* 51, 435-452.
6. Callan, J. P. (1994) Passage-level evidence in document retrieval. *Proceedings of ACM SIGIR Conference* (pp. 302-310). New York: ACM.
7. Cardinale, L.A. (1991) Conceptual models and user interaction with computers. *Computers in Human Behavior,* 7, 163-169.
8. Carpenter, D. (2002) The paperless chase. *Hospitals and Health Networks, 76*(1), 47.
9. Chen, H.C., and Dhar, V. (1991) Cognitive process as a basis for intelligent retrieval-systems design. *Information Processing and Management*, 27, 405-432.
10. Collen, M. F. (1987) Health care information systems: A personal historic review. *Proceedings of ACM Conference on History of Medical Informatics* (pp. 123-136). New York: ACM.
11. Dimitroff, A. (1992) Mental models theory and search outcome in a bibliographic retrieval system. *Library and Information Science Research,* 14, 141-156.
12. Eveland, W.P., Jr., and Dunwoody, S. (2000) Examining information processing on the World Wide Web using thinkaloud protocols. *Media Psychology*, 2, 219-244.
13. Fein, R.M., Olson, G.M., and Olson, J.S. (1993) A mental model can help with learning to operate a complex device. *Proceedings of the Conference on Human Factors in Computing Systems [Interact '93]:* 157-158. New York: ACM.
14. Frisse, M. (1992) The health of the computer-based patient record. *Academic Medicine, 67*(7), 441-443.
15. Gregory, J., Mattison, J. E., and Linde, C. (1995) Naming notes: Transitions from free text to structured entry. *Methods of Information in Medicine*, *34*, 57-67.
16. Halasz, F.G. and Moran, T.P. (1983) Mental models and problem solving in using a calculator. *CHI Proceedings*, 212-216.
17. Hearst, M. A., and Plaunt, C. (1993) Subtopic structuring for full-length document access. In *Proceedings of the Sixteenth Annual International ACM SIGIR Conference on Research and Development in Information Retrieval* (pp. 59-68). New York: ACM.
18. Herbst, A.J. (1989) The evaluation of user interface design in medical software. *Medinfo,* 368-371.
19. Kieras, D.E., and Bovair, S. (1984) The role of a mental model in learning to operate a device. *Cognitive Science*, 8, 255-273.
20. Kluge, E.-H. W. (1996) The medical record: Narration and story as a path through patient data. *Methods of Information in Medicine, 35*, 88-92.
21. Laerum, H., Ellingesen, G., and Faxvaag, A. (2001) Doctors' use of electronic medical records systems in hospitals: Cross sectional survey. *BMJ, 323*(7325), 1344-1348.
22. Melucci, M. (1998). Passage retrieval: A probabilistic technique. *Information Processing and & Management,* 34(1), 43-67.
23. Nygren, E., and Henriksson, P. (1992) Reading the medical record: I. Analysis of physicians' ways of reading the medical record. *Computer Methods and Programs in Biomedicine*, 39, 1-12.
24. Panko, W., Silverstein, J., and Lincoln, T. (1999) Technologies for extracting full value from the electronic patient record. *Proceedings of the 32nd Hawaii International Conference on System Sciences.* New York: IEEE.
25. Poullet, L., Pinon, J.-M., and Calabretto, S. (1997) Semantic structuring of documents. *Proceedings of the 3rd Basque International Workshop on Information Technology (BIWIT)* (pp. 118-124). New York: IEEE.
26. Rossi Mori, A., Galeazzi, E., Consorti, F., and Bidgood, W. D. (1997) Conceptual schemata for terminology: A continuum from headings to values in patient records and messages. *Proceedings/AMIA Annual Symposium*, 650-654.
27. Royal College of General Practitioners Health Informatics Task Force. (1999) *Scoping the primary care view of the option for the development of the EPR (ScopeEPR).* London: Author.
28. Salton, G., and Allan, J. (1993) Selective text utilization and text traversal. *Hypertext '93* (pp. 131-144). ACM.
29. Spiegel, A.D, and Springer, C. R. (1997) Babylonian medicine, managed care and Codex Hammurabi, circa 1700 B.C. *Journal of Community Health, 22*(1), 69-89.
30. Thompson, T. R. (1996) Easier said than done. *Hospitals and Health Networks*, 70(13), 29-31.