Florida Breast Cancer Coalition Research Foundation (FBCCRF) Grant

Research Project a *Cognitively-based System of Perception and Interaction for CAD-assisted Mammography Interpretation*:

Final Report 2006 - 2009

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This final report is to describe the completed FBCCRF research project *A Cognitively-Based System of Perception and Interaction for CAD-Assisted Mammography Interpretation* (July 1, 2006 – June 30, 2009). With the guidance and support from the Institutions, grantee student's Mentor, Major Professor, and other doctoral committee members, the grantee student completed her planned work. Here the grantee student will summarize the project's objectives, describe work progress, and report findings throughout this research project. A financial report will be submitted if required.

Project Objectives

The objective of the project is to identify the problem-solving model and cognitive components underlying non-cognitively-based and cognitively-based hypermedia learning. The other objective is to find out how the integration of cognition-based activities influences the performance of mammogram readers and if and how cognitively-based hypermedia training can help enhance retention, recognition, and other performance in mammography interpretation education and decrease errors in detection and diagnosis. Another objective is to design a hypermedia prototype tutoring system on the basis of the identified cognitive model, factors, and empirical evidences. It will build up the residents' confidence, skills and experience in extending their perception with computer-based interactions and knowledge construction. With this training, mammogram interpreters may improve their accuracy, flexibility, and automaticity in their working performance.

Project Achievements and Progress

Generally, the planned activities have been completed during the project period of time (July 2006 - June, 2009). Here are the specific tasks carried out: (1) To construct a perception and problem-solving model of human cognition-based mammography interpretation; (2) to analyze and identify if and how computer-based interactions reduce the novice-expert differences in radiological observation, findings, diagnosis, diagnostic accuracy, reasoning strategies, errors, and other processes; (3) to develop and test technology and prototype intelligent tutoring system based on the cognitive model and task analysis from the previous work; (4) to apply methodology of cognitive science and results in empirical research to develop requirements, design guidelines and recommendations for computer-based training in mammography interpretation; (5) to continue to develop requirements, design guidelines and recommendations for cognitively-based hypermedia training system in mammography interpretation; (6) to document the studies by making a record of the literature, methods, proposed data analysis, and expected interpretation, discussion, and findings; and (7) to become an independent research investigator through this training program. In particular, the following detailed tasks were focused on:

(a) Studied literature in cognitive psychology, perception, medical imaging, CAD, information processing, instructional design, and research methods.

(b) Prepared interview questions and conduct interviews and observations to radiologists, instructors and other professionals for task and content analysis of mammography interpretation.

(c) Formulated a cognitive model of expert problem solving strategies, knowledge base and process control for mammogram interpretation with CAD as the second reader; Make discussions and draw conclusions on the findings.

(d) Designed the structure and modules of the system by applying empirical findings in cognitive science and previous studies.

(a) Developed requirements, design guidelines and recommendations for computer-based training in mammography interpretation.

(f) Developed principles and guidelines for cognitively-based hypermedia training system for CAD-assisted mammography interpretation.

(g) Made report of the findings and the creation of the proposed intellectual tutoring system.

Findings

Based on these three years' investigation, some of the findings were identified and listed as follows:

To improve the capabilities and performance in visual category tasks, particularly in mammogram reading, computer-based training (CBT) has potentials. First, training is necessary and possible to increase perceptual expertise. On one hand, variability exists in people's visual skills and performance, demanding instruction. On the other hand, psychologists and neurophysiologists have found the evidence of the plasticity of human visual cortex (Goldstein, 2002). Training and learning can change the structure of the sensory cortex, evoke neural firing, and enhance transfer ability. Second, compared with print media, computers can provide the affordances in facilitating visual concept training for its potential functions in human-computer interactions, capabilities in storage, retrieval, and image compression, as well as the benefits of convenience and cost-effectiveness.

However, researchers reported the lack of CBT methods in this area (Sharples, 1991). In practice, online courses and materials in medical education, particularly in mammogram reading, often adopt an information transmission model due to its pedagogical tradition, turning learning passive and learners as receptacles. Although some instructional methods started to be used, such as tutorials, simulations, and games, they are still at the initial stage of development in terms of their “micro-level” instructional strategies. Moreover, previous studies have shown the effects of CBT on student achievements (Bangert-Drowns, Kulik, & Kulik, 1985; Blok). However, theoretically and methodologically, there is no agreement on how to study these newly emerging technologies. More specifically, little research has been conducted in what instructional strategies, events, or activities in CBT can effectively enhance visual category learning.

Consequently, this shortage of visual learning research is problematic in medical and other visual-rich areas. For example, the ability to perceive, discriminate, and interpret mammogram features is critical for the early detection and diagnosis of breast cancer (Clark, 2005). Misreading mammograms is a serious problem, resulting in false positive and false negative with consequences of unnecessary biopsies and missed diseases. These medical errors have triggered lawsuits and hence the attrition of radiologists working toward and with this specialty. On the other hand, mammogram screening is in high demand in clinics, asking for more experts in this area (Bassett et al, 2003; Elmore et al, 2005). Adding to the seriousness of the problem, it is usually expensive, expert-availability-limited, and time-consuming to train radiologists. Bassett and his colleagues (2003) surveyed 201 residents at 211 accredited radiology residencies. They found that 87% of residents regarded mammography interpretation more stressful than reading other images. Although 65% of them valued sub-specialists in this area, 64% of them were not willing to take breast imaging in their fellowship. Furthermore, 63% refused to spend 25% or more of their clinical practice time in interpreting mammograms. They also identified the reasons for these phenomena, including comparatively low interest, high stresses, and possibilities of lawsuits. The researchers concluded with the lack of willingness to do mammography among residents for fellowship and future practices. As such, image reading and visual learning research deserve more attentions in order to improve mammogram readers' performance, decrease their errors, stresses, and fears, increase their confidence and self-efficacy, and eventually satisfy the high demands of corresponding professionals.

In radiology resident education, IT has raised concerns for emerging computer-assisted modalities and technology-based education. Radiology is a visual rich area. The reality of this visual area is that medical images have gradually been computerized, including such new modalities as digital mammography, ultrasonography, computer tomography, magnetic resonance imaging, etc. (Gunderman, Kang, Fraley, & Williamson, 2001). Particularly, with the advent of digital mammograms, evaluating and making reports on computers have become residents' full-time jobs. Mammogram reading rotations, varying from facility to facility, usually last for approximately 12 weeks 8 hours per day with most of the time focusing on reviewing mammograms on computers. Another phenomenon in radiology resident education is the increasing development and use of technology-based education, including Websites, online teaching files, and educational software. Actually, the application of instructional technology in radiology education may decrease the investment of clinical hours into education so that radiologists can contribute comparatively more hours to diagnostic activities. However, without studies in how to apply IT in radiology, its benefits may be questioned, challenged, and compromised Technology-based teaching materials are emerging and increasing, but there is a lack of instructional design practice and research support for these projects.

Furthermore, mammogram reading has some crisis in both its teaching and learning. The shortage of academic radiologists in teaching was identified (Gunderman, Heitkamp, Kipfer, Frank, Jackson, & Williamson, 2003). Radiologists are usually overloaded with clinic work and conferences. When they play multiple roles of physician, faculty researcher, and educator, they may probably have to prioritize these tasks with clinical work on the top of the task list because of institutional responsibilities. Therefore, they do not have adequate time for designing instructional programs. Instruction in radiology tends to result in an ad hoc apprenticeship, lack of standard and detailed instructional objectives, learning activities, and assessment. The other problem in resident teaching is the random and discrete cases. This results in some difficulties for the learners to relate their prior knowledge to new cases. Structuring knowledge has become one of the most difficult tasks in radiologists' professional life. Furthermore, residents are in short of self-assessment schemes in their learning process. This may result in lack of opportunities for them to think over the relationship among images they read. They may not know what they need to make up for further progress. On the other hand, medical residents are not willing to contribute to this specialty because of low reimbursement and concurrent lawsuits. The motivation among them was reported pretty low compared with those in the other medical areas (Bassett et al, 2003). These problems have resulted in a shortage of qualified mammography radiologists in clinics.

Through studying a computer simulation model practice-based education, an ideal framework was found and set up for the proposed program. It was found that practice-based education provides learners with cognitive tools, supporting their perceptual problem-solving processes, extending their capabilities, and improving their practices. Learners can internalize the mental models in mammogram reading through multiple cognitive-based and pedagogical sound tools and activities. Practice-based education is the framework of this proposed study.

Problem solving is regarded as a higher-level intellectual skill, defined in a widely accepted hierarchy in instructional design, with the other lower-level skills in the order of complexity, including discrimination, concepts, and rules (Gagne, Wager, Golas, & Keller, 2005). Cognitive scientists and educators are interested in problem solving because it widely exists in almost every domain of learning and real life (e.g., Bruning, Schraw, Norby, & Ronning, 2004; Jonassen, 2004). Humans actually solve many problems every day no matter whether these problems are math, science, reading, writing, or just everyday routines.

Medical doctors solve diagnostic problems in a great many of areas, ranging from physical examination, internal medicine, to radiology (Norman, Coblentz, Brooks, & Babcook, 1992). However, researchers in cognitive sciences noted that the problems in such an area as radiology differ from those in some other medical areas because similarity-based reasoning is essential in solving radiology problems (Norman, Coblentz, Brooks, & Babcook, 1992; Wood, 1999). That is, diagnosis is established on the basis of pattern recognition and the diagnostic decisions of previous cases.

The following problem-solving model was identified in interpreting mammograms (Luo, Eikman, Kealy, Qian, 2006):

1. Evaluation of the technical quality, including adequate coverage of the breast, correct labeling and positioning, exposure, display.

2. Evaluation of breast "density", overall structure.

3. Recognition of abnormalities.

4. Describe abnormality.

5. Formulate an opinion with recommendation.

Collins (2000) wrote an article on developing the chest radiology curriculum for resident education. She emphasized the general principle that a curriculum is not just a list of topics, but includes learning goals, objectives, content, faculty, methods, and evaluation. She pointed out the importance to guide residents to become active and reflective learners, who can be responsible for and direct their learning and learn from their experience. She maintained the importance for learners to obtain some effective and efficient learning skills. She also illustrated it with an example of a task that demands higher-level learning. In this case, pattern recognition is insufficient and residents need to analyze and assimilate clinical information and image findings to synthesize diagnosis. It seems that the case she presented is a difficult one, so problem solving is highlighted (Lesgold, Rubinson, Feltovitch, Glaser, Klopfer, & Wang, 1988; Norman, Coblentz, Brooks, & Babcook, 1992). Here the radiologist researcher defined pattern recognition as “having seen a number of similar cases before” (p.110). Compared with the analysis and synthesis skills used in dealing with complex cases, pattern recognition was defined as lower-level learning in radiology education. However, this also justifies that pattern recognition needs to be learned early in resident education because lower-skills need to be learned before higher-level ones and the sequence of an ascendancy of complexity is important in instructional design, according to some general instructional design principles, such as the hierarchy of intellectual skills and elaboration theory (Gagne, Wager, Golas, & Keller, 2005; Reigeluth, 1999). The underlying cognitive reason for this sequencing can be that automaticity of lower-level skills can leave more cognitive faculties to higher-level information processing (Sweller, 1999). In addition, from the perspective of development of expertise, novices have insufficient prior knowledge, depth of processing strategies, and interest to learn higher-level knowledge and skills. Therefore, pattern recognition needs to be learned before image interpretation in radiology education.

With the above-listed work, the manuscripts of two papers are in preparation. Here are the abstracts of these two papers:

Abstract 1: To meet the demands of visual learning, particularly in mammogram reading, it is necessary to study computer-based training methods to increase performance. These methods can have potentials in improving image reading, leading to accurate detection and diagnosis in radiology. Therefore, the purpose of this research is to propose and test some CBT strategies, some technology-enhanced constructive activities in particular, to improve mammogram readers' performance.

Abstract 2: While interactive instruction has been found effective in some areas, interactive design has seldom been examined in the context of mammogram reading training, especially with hypermedia affordances. The existing interactive patterns in some other areas may illuminate interaction design in the studied area. A comparative study was conducted to derive some patterns for computer-based training in mammogram reading.

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