Computers in Radiologic Education

Computer-Aided Instruction in Radiology: Opportunities for More Effective Learning

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Little doubt remains that computers will play an important part in the future of education. What should be of special concern to radiologists, however, is the unique way that computer-aided instruction differs from printed text and its potential for facilitating education in medical imaging. Adapting to this media will require a mental shift on the part of educators as well as students. As the sophistication of the student increases, attention will shift from the novel presentational power of the computer to the opportunities that computers offer to expedite learning and to evaluate the extent to which knowledge is mastered.

Background

When it was recognized that computers were capable of more than mere calculation [1], educators considered the possibility of computer-aided instruction as a means to improve human learning. Early efforts initiated as long ago as the 1960s seemed premature. The projects of that time failed for the most part because the technology depended on costly mainframe computers. Moreover, educators were several layers removed from didactic implementation because professional programmers were needed for the complex computer operating systems.

Recent advances in microelectronics, with prices now determined by consumer rather than scientific markets, have created desktop computers sufficiently powerful to offer more opportunities for computer-aided instruction. Moreover, recognition that humans interact easily with visual objects has stimulated the development of symbolic graphics to facilitate communication between students and computers. An important advance has been the introduction of an electronic pointing device, the mouse, that eliminates the need for some keyboard typing [2]. Human-machine interaction improved when screens full of text were changed to screens that showed ideograms (icons) (Fig. 1) and pull-down menus from which users can select commands rather than having to type them from memory [3]. These implementations have made

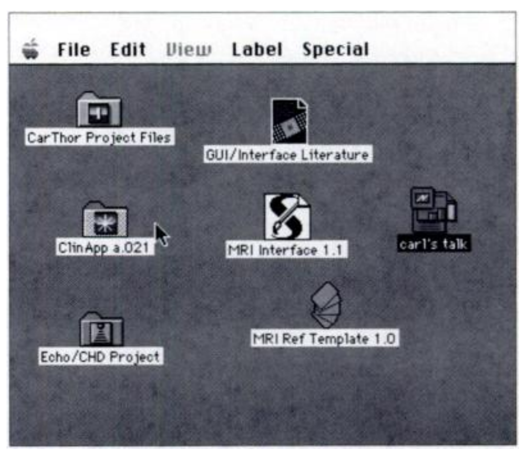

Fig. 1.—Graphic user interface uses mouse-clickable icons and screen position to guide user interaction, does not rely on user's memory and knowledge of syntax.

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the human-computer interaction more intuitive so there is less need to memorize rules of textual syntax [4]. Various manufacturers have introduced different but readily understandable methods for user interaction with the computer (user interfaces), whether it is the Mac operating system (OS) for the Macintosh; OS/2 for the IBM; and Windows for IBMs and clone manufacturers; for Motif, Open Look, and so on for the powerful Hewlett-Packard or Silicon Graphics workstation machines [5]. In addition, the development of more comprehensible "authoring" (vide infra) computer languages permits even minimally computer-competent persons to custom-program some aspects of their own interaction with the computer.

Radiology and Computer-Aided Instruction

It is natural that diagnostic radiology, a specialty involved with medical imaging, should lead in using computer-aided instruction. Most radiologic education is based less on verbal description than on repeated visual experiences. A large collection of images, stored and accessible at electronic speeds, is a valuable learning resource for radiology. Both individual investigators and professional societies such as the American College of Radiology recently have begun to create teaching files on randomly accessible videodiscs (a hybrid technology with both digital and analog aspects).

On-line, fully digital image archives accessed on a desktop computer were not practicable until the past few years. Now they are becoming widespread with the increasing availability of picture archiving and communication systems and compact discs with read-only memory (CD-ROM) as inexpensive large digital storage media.

A distinction should be made between the high spatial and density resolution needed for archiving diagnostic X-ray images (radiographs) in a radiology department and the more limited demands of a teaching file of images. The requirements of a teaching file can be satisfied by small desktop computers. Computer-aided instruction that incorporates radiographs can already exceed the quality of images in print in radiology journals. Moreover, conventional radiographs, images that place the highest spatial resolution demands on computer screens, are a decreasing portion of clinical practice. The inherently digital techniques of CT and MR imaging are well suited for computer displays.

Educational Limitation: The Problem of Feedback

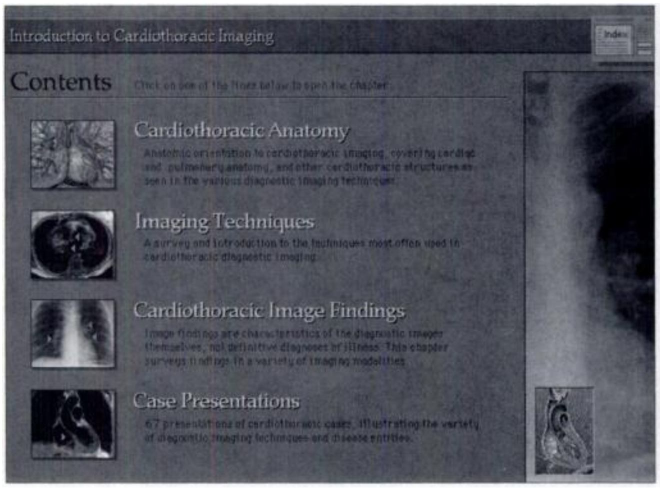
The means by which people pursue their education should be considered when deciding whether computer-aided instruction is advantageous. Reading textbooks and journals and attending lectures and formal courses are the mainstay of today's education. Although printed matter has the convenience of portability and is simple to use, its conventional form lacks completeness. A heavy 400-page book rarely has more than 1200 images and cannot convey sound and movement. Even in booklets with self-test modules, reading is a passive activity that cannot satisfy a user's need for demonstrated accomplishment. Although the organization of information in books is guided by the table of contents and the index, printed matter cannot provide automated word searches or the ready reordering of content sequence, both of which are possible with a computer. Most important, books are primarily vehicles of text—descriptions that lack the immediacy provided by computers, which make active participation by the student possible. Print is a static medium, not always compact, not always inexpensive, and certainly not dynamic. Formal courses require that specific time be set aside, often require travel, and are not easily customized for the various educational levels of the participants. These limitations can be addressed by properly designed computer-aided instruction.

Hypertext and Multimedia

Most early educational software applications used hypertext [6, 7], which allows a user to browse through a system that links and cross-references text and graphics in a nonlinear, interactive format that responds to the user's requests for more information on a particular subject [8]. For example, to get more information on a word or graphic, the user would simply point with the mouse to that area on the computer screen and click the mouse button (Fig. 2). A program for Macintosh computers called HyperCard emulates a collection (stack) of cards, with each self-contained card filling the display screen but carrying visually identified electronic links to other cards [7]. When the user questions an interesting feature on a card, a mouse click will branch to another card, play a video sequence, call up new text, or in some other way bring a new set of related information to the user. Thus, the user can explore the program in a heuristic, self-paced manner that takes full advantage of the computer's ability to organize, correlate, store, and retrieve information. Multimedia is an extension of the same concept to include audiovisual information, sound, or three-dimensional graphics (Fig. 3). The most favorable setting for learning is a readily available, rich, interactive, nonlinear environment, and a student motivated by curiosity.

Authoring Languages

Authoring programs are software environments that allow users with little or no previous experience with traditional computer programming languages to integrate text, audio and video material, computer graphics, and animation into educational and training applications that take full advantage of the computer's easy-to-use graphic interface. Although authoring languages are no substitute for data base management software, they share some structural features with conventional data base programs. Text is stored in fields on cards (cards are analogous to records in conventional data base terminology) and can be searched and sorted rapidly. Some authoring programs, such as HyperCard (Apple Computer, Cupertino, CA), SuperCard (Allegient Technologies, San Diego, CA), and ToolBook (Asymetrix, Bellevue, WA), also incorporate a full range of graphics tools in a powerful English-like programming language called a scripting environment. HyperCard is an exemplary authoring language in which the card is the fundamental unit in a stack of cards. HyperCard allows only one card at a time to be visible, regardless of screen size (Fig. 4). Users browse through HyperCard applications by moving from one card to another, similar to flipping through a stack of index



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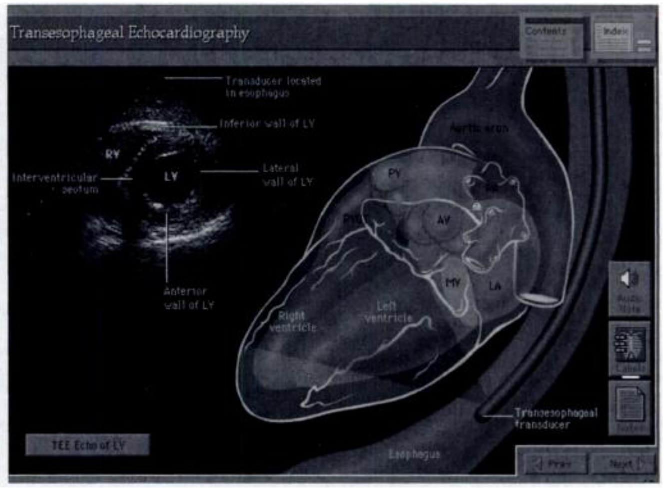

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Fig. 2.—Contents screen of computer-aided instruction module on cardiothoracic imaging. Nearly all pictures or text can be mouse-clicked by user to branch to additional information.

Fig. 3.—Parts of this computer-aided instruction screen developed for teaching transesophageal echocardiography can be mouse-clicked to run real-time video sequences of echo images. Clicking on graphic illustration will bring forth hidden labels.

cards. Cards have two independent layers: a transparent foreground layer of graphics, buttons, and text fields unique to a particular card; and a background layer of graphics, buttons, and text fields that may be shared by many cards.

The primary virtue of HyperCard is its ability to link associated graphics, text, and video sequences into an integrated web of information. Figure 5A illustrates the dynamic linking between graphic objects on a single card. When the student moves the mouse to place the cursor over the heart illustration in Figure 5A and clicks the mouse button, a label naming the anatomic feature pops up temporarily if the mouse button continues to be depressed (Fig. 5B) but disappears to give an unimpeded view of the illustration when the button is released.

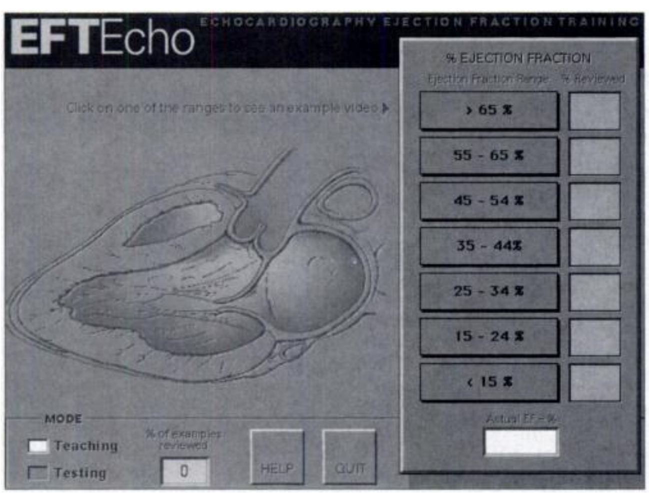


Fig. 4.—Screen from computer-aided instruction program for training visual estimation of left ventricular ejection fraction from echocardiography. Clicking on right-hand buttons brings up overlay echo video sequences that show different ranges of left ventricular dysfunction. Self-administered quiz tests learner's ability to make distinctions.

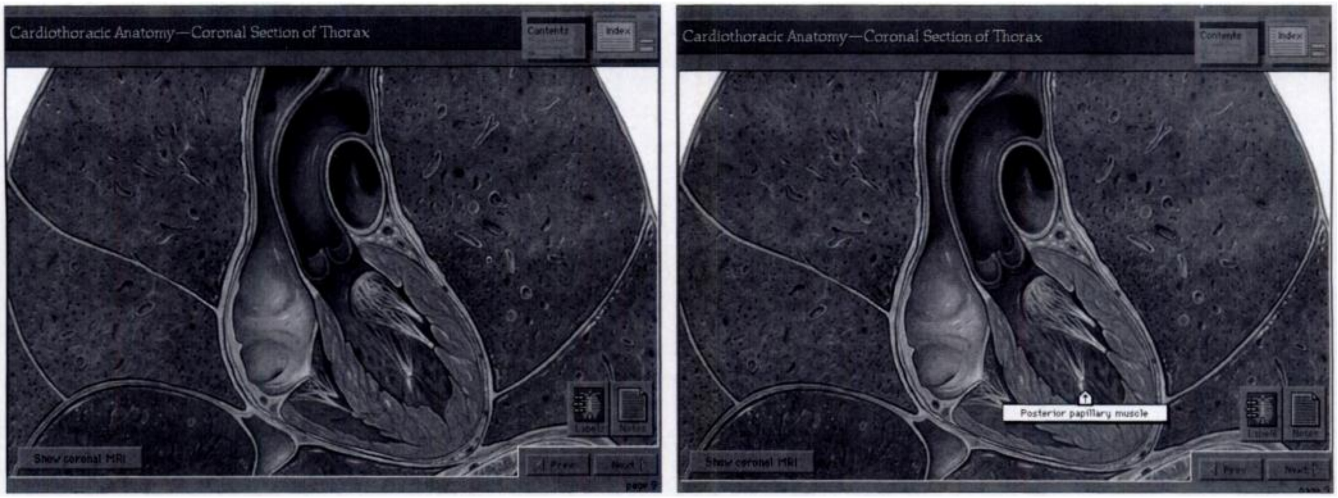
The ability to create multiple levels of depth and complexity by linking illustrations or even audio (Fig. 6) in a multimedia application is a strength of all authoring programs. The screen illustrated in Figure 2 branches directly to more than a dozen other screens containing related anatomic graphics and animation, literature references, menu options, and program help information; these screens in turn are linked to more than 30 digitally compressed video sequences.

Information Storage

Prices for hard drives and memory are falling, and CD-ROM technology is maturing. CD-ROM digital discs with a capacity of 650 megabytes (the equivalent of about 8 linear feet of books or journals) share the technology and low manufacturing cost of audio compact discs. Multimedia computers with a CD-ROM drive cost approximately $2500. The CD-ROM gives the stand-alone user a portion of the information access of networks. The number of CD-ROM titles available is growing exponentially, although the breadth of current offerings is limited. The analog cousin of the compact disc, the 12-in. laser videodisc, is available in a variety of radiologic titles from several sources, including the American College of Radiology. Some of these titles are geared to a simpler (but just as effective) technology because videodiscs can be controlled by bar code wands from printed guidebooks.

Networks

Network access among institutions connected through the National Information Infrastructure, known as the Internet, allows worldwide electronic transfers in excess of 1 megabyte per sec, and the communication speed of the Internet is rising. Once in place, network accessibility will offer not only educa-



A B

Fig. 5.—Screens of anatomic illustration that is part of program on cardiothoracic imaging.
***A*, Icons on edges permit users to navigate to other related subject matter.**
***B*, When user moves mouse over any part of screen illustration and presses down on mouse button, pop-up label gives name of anatomic structure.**

tional applications but also the ability to search immense data banks from remote hosts for specific, updatable information. In the near term, however, the CD-ROM will probably be the mainstay of home learning systems because it is a large inexpensive storage media within existing technology.

Self-Assessment for the Future

Computer-aided instruction can function on a higher plane when the user can access vast amounts of information at reasonable cost. There is, however, a distinction between access to information (e.g., clinical image data bases, collections of patients' records, or Medline) and access to specific learning activities; it is the difference between drinking from a fire hose and sipping from the fountain of knowledge. The relationship between information access and computer-aided instruction may be likened to the process by which facts become knowledge and knowledge in turn becomes understanding. The diversity of new diagnostic imaging tools and the rapid evolution of the basics of medical knowledge demand a more efficient, more pervasive, and more personal form of learning than journal subscriptions (now all too numerous and so diverse that most clinicians are chronically behind) and occasional professional meetings. Computer-aided instruction is most successful when it provides extensive, focused content conveniently and intuitively accessed by point-and-click operations from the computer screen. The user must be made aware of didactic paths that are available. Navigation through the enormous amount of information available on a single CD-ROM must remain intuitive in order to avoid aimless, nondirected browsing.

The most important untapped aspect of computer-aided instruction is its capacity to generate interactive quizzes and to guide self-assessment, including remedial exercises, without embarrassment to the learner. All goal-oriented learning needs feedback so that the student knows when the learning objective has been achieved (Fig. 7). Current research is being done with approaches that use artificial intelligence (a set of predefined rules that execute when certain conditions

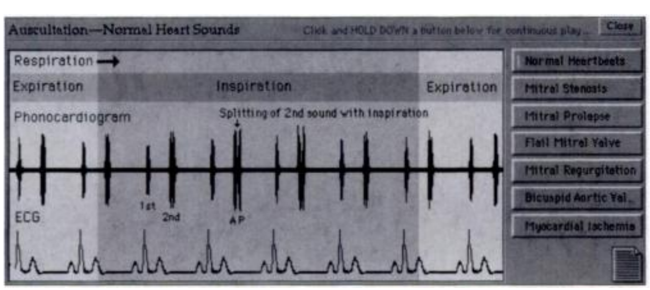


Fig. 6.—Screen from audio resource portion of computer-aided instruction program shows normal and stethoscopic auscultation of heart.

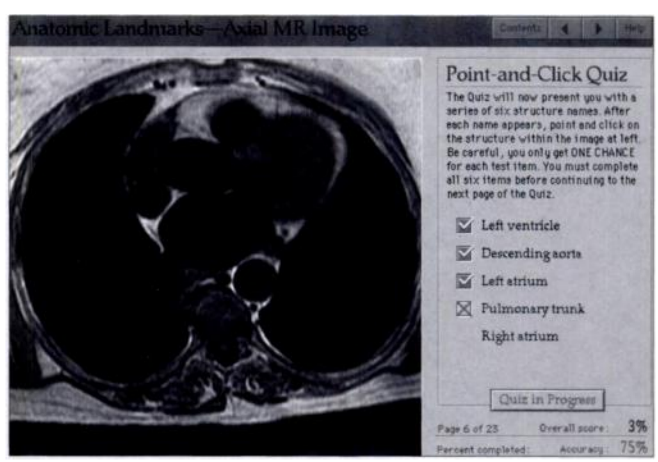


Fig. 7.—Self-administered computer quiz requires user to point mouse at specified structures on medical image. Interactive scoring provides instant feedback.

are met) as a tool to guide learners of different abilities through different paths in the same educational content. Greater exploration of this aspect of computer-aided instruction and its correlate, credentialing and accreditation, can be expected in the near future. Continuing medical education will be a standard option for nearly all future computer-aided instruction because it is easy to design into software and can be instantly validated when the computers are networked.

Conclusion

Computer-aided instruction, with its newly acquired capacity to provide multimedia (i.e., text, animation, sound, and video) integration, is an ideal medium for individualized, classroom-independent learning. The power of the desktop computer makes it easy to build course materials and to organize and develop more effective instructional strategies. Computer word processing, "outline" functions, and data bases help organize hierarchies of information and findings and provide simulations for complicated conceptual processes. Computers can never replace an inspired teacher, but there is now no question that computers can play a supportive role in the educational process. Their ability to provide individual learning paths, to offer a self-paced environment, and to encourage personal exploration of detailed knowledge no longer provokes the skeptical glances of a few years ago. Effective computer-aided instruction, however, requires careful, thoughtful design that fully exploits the potential of the media. Computer-aided instruction must be engaging, spontaneous (perhaps even humorous), and rich in images and dynamics, and it must express a philosophy of teaching. Computer environments are more exacting than print media and require a precise and predictable link between the hierarchies of organized information; therefore, the careful construction and continuous improvement of computer-aided instruction are essential.

From the medical standpoint, learning environments that are less expensive than traveling to meetings, that are more dynamic, and that provide a greater range of linked information than books or journals are compellingly attractive. Computer modules that provide self-assessment using quizzes that offer recursive remedial procedures make an educational environment that is virtually complete.

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