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Hypermedia Techniques for Diagnostic Imaging Instruction: Videodisk Echocardiography Encyclopedia[1]

Because of the visual complexity of medical images and the intensive tutorial experience required to develop image recognition expertise, professional training programs have concentrated on educating limited numbers of experts. Videodisk and CD-ROM (compact disk read only memory) image storage media now make it possible for a microcomputer workstation to provide a learning environment substantially equivalent to that of conventional time-consuming tutorial methods. A demonstration hypermedia program on echocardiography was constructed that provides a user-controlled learning environment with instant access to 54,000 video frames encompassing 1,200 clinical items. The instructional module is controlled by a microcomputer, which provides electronic linkage to relevant graphics, animations, text, categorized data bases, and digitized sound. The system has been successfully used in a residency program as the primary instructional tool for achieving an intermediate level of clinical expertise. Hypermedia offer substantial advantages over conventional books as a clinical reference source.

Index terms: Computers • Education • Heart, US studies, 51.12987

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A major impediment to increasing the number of image-knowledgeable individuals is that most "image knowledge" is phenomenological—at best only partly verbal—and thus is acquired largely from experience with images. The specialist must be familiar not only with the canonical presentation of a disease entity but also its spectrum of variations. For example, the American Society of Echocardiography recommends experience with more than 150 clinical cases as a basic educational minimum. In attempting to acquire expertise, clinicians must surmount the range of variation and closeness of perceptual overlap that create complexity for the physician viewing medical images. It follows, therefore, that as vehicles for information and training in radiology, print media (books and articles) are greatly handicapped, since their capacity for text and illustrations is limited, access to information is dictated by the table of contents or index, and grayscale fidelity is limited. In addition, print media are totally incapable of portraying real-time motion and sound, which are essential aspects of some medical images.

Though often prematurely heralded in the past, progress in microelectronics has now reached a critical threshold in power, speed, reliability, and commercial availability that allows it to be used meaningfully in education and diagnostic consultation. Though new tools often become successful by simulating established methods, the electronic workstations have unique properties that imply potential for revolutionary changes in methods of learning, particularly in fields in which images play a major role.

STATE OF THE ART OF COMPUTER-AIDED INSTRUCTION

Newly available microcomputer-controlled videodisk workstations offer sufficient on-line mass storage capacity of images that makes possible a totally novel approach to instruction in medical imaging. Central to this approach is a recently coined term *hypermedia*, which has been promoted by several personal computer visionaries (1–3) and which, in its popularized form, has gained attention for its unique power in the management of large repositories of complex information (1). The term should not be confused with *multimedia*, which is merely a mix of audiovisual techniques. *Hypermedia* connotes a highly integrated electronic environment, which allows a user to interactively peruse a very large collection of electronically linked information consisting of real-time moving color video images, sound, text, and electronically searchable data banks (4,5). Several manufacturers have implemented the hypermedia concept in a complete instrument. One well-known example is the Macintosh hardware with HyperCard software (Apple Computer, Cupertino, Calif), but the power of the concept has been grasped by other manufacturers,[2] who are introducing competing implementations. These instruments integrate personal computers with fast-access, multi-hundred-megabyte data storage devices (hard disk and

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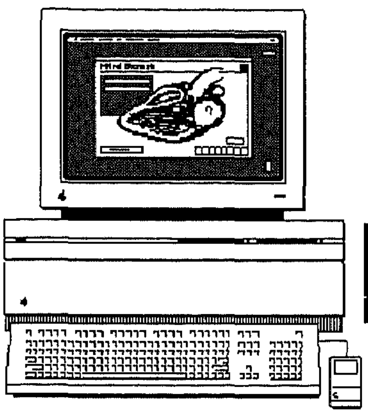
[2] IBM, Valhalla, NY; NeXT, Cupertino, Calif; Sun Microsystems, Mountain View, Calif; Digital Equipment, Marlboro, Mass.

Abbreviation: CD-ROM = compact disk read only memory.



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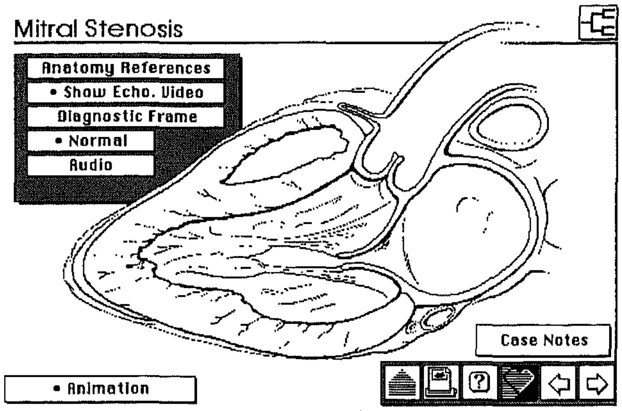

2.

Figures 1, 2. **(1)** Hardware configuration of a hypermedia learning workstation composed of a microcomputer and its monitor linked to a videodisk player and its monitor. **(2)** A typical card in a HyperCard educational application contains text, graphics, and buttons (shown as little rectangular icons activated by being selected with the mouse), which allow the user to navigate through the stack and, in this case, to play specific videodisk sequences.

optical disk, such as CD-ROM [compact disk read only memory]); touch-screen or mouse-oriented point-and-click selection from menus or symbolic graphics (icons); randomly accessible real-time video segments from videodisks; and digitized sound. An essential feature of these hypermedia products is that they provide an integrated tool for creating or using a course in which a student's path through the material can be either teacher directed or random, depending on the intent of the author (4). The authoring languages used in this generation of hypermedia tools permit logic control of user interface, user interaction, display of data, display of video sequences, and sounds.

Because development of medical imaging expertise depends on tutorial methods and the accumulation of repeated visual experience with a wide variety of images, the instant access to images offered by videodisks provides an optimal technology for teaching, so long as the original medical images are compatible with the resolution and gray-scale properties of video. Thus, videodisks are ideal storage media for the real-time color and audio aspects of echocardiography and body ultrasound and for the windowed images of nuclear medicine, computed tomography (CT), and magnetic resonance (MR) imaging. Though video has insufficient spatial and gray-scale resolution for proper storage of radiographs or the full gray-scale dynamic range of nonwindowed CT and MR imaging, such images may be stored digitally on CD-ROM and still be incorporated into the learning workstation.

As a project to demonstrate the impact of this hypermedia concept on medical teaching, we constructed a comprehensive instructional module on echocardiography. For the past year, this module has been successfully used in a residency training program as the sole primary method for giving trainees greater than basic-level training in echocardiography. After a few hours of using the system, residents, in their first clinical experience with echocardiography, were fully oriented to imaging planes and image findings and demonstrated an intermediate level of clinical expertise.

ECHOCARDIOGRAPHY HYPERMEDIA PROJECT

To conduct the hypermedia demonstration project, we used a Macintosh II personal computer with a hard disk drive and a standard laser videodisk player (LDV 6000A; Pioneer Communications of America, Upper Saddle River, NJ). The optimal workstation for our instructional module consists of a Macintosh II or SE computer and a laser videodisk player with its own monitor, although the minimum hardware necessary to run HyperCard is a Macintosh Plus computer with at least 1 megabyte of RAM (random access memory), a hard disk, and a 4.2 version (or greater) Macintosh operating system.

We used a specially developed videodisk (Yale University and the Educational Technology Branch, National Library of Medicine), which contains 54,000 randomly addressable individual images. The clinical case material is divided into more than 1,200 items viewable in either endless-loop moving sequences or still frames, as appropriate. Patient cases were selected from more than 14,000 diagnostic studies performed over a 12-year period at Yale–New Haven Hospital. More than 160 individual cases were selected for this disk. Virtually the full spectrum of diseases diagnosable by means of echocardiography is available on the disk. The most common diagnostic types are represented by multiple cases so that a full range of disease severity and image quality is available in a realistic instructional environment. Although much of the videodisk content stresses two-dimensional real-time imaging, all other techniques, such as M-Mode, pulsed and continuous-wave Doppler, and color Doppler flow imaging, are fully represented as diagnostically appropriate. In addition, there are segments on transesophageal echocardiography.

Each item on the videodisk is indexed in a data base residing on the hard disk. The data base files the location of each video item on the hard disk. It also files chief imaging findings and has additional fields for the type of view and for extensive clinical records of particular patients from whom the images were obtained. A clinical record includes fields that list the patient's age, sex, clinical cardiac history, catheterization data, pertinent review of organ systems, and nuclear medicine results and other data.

The videodisk is a key element around which the instructional program centers, since it offers access to original clinical images. In the Macintosh workstation (Fig 1), the program operates within the HyperCard

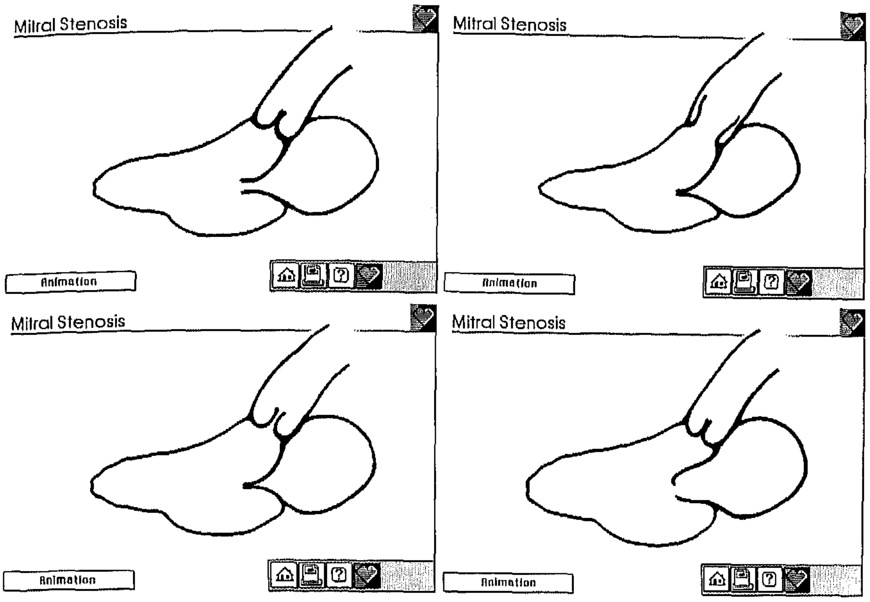

Figure 3. Four frames (cards) from an animation series depicting valve movement in mitral stenosis. For simplicity, only the structures most diagnostically important in echocardiography are depicted. The full animation cycle consists of nine cards.

software environment, with the user employing a mouse-oriented, point-and-click interface to access any segment of the instructional module. The hard disk of the computer holds graphics concerning anatomy, views, and diagnostically relevant frames and animations. It also holds categorized data bases and digitized audio renderings of stethoscopic sounds for selected diagnoses. Each diagnosis is supported by texts on clinical background (demographics), causes, findings, and where relevant, severity. The user interface software provides integrated access to all of the above types of information through point-and-click selection known as "mousing." The principal order by which the user accesses information is to select first the cardiac diagnosis and then the view. The diagnosis is illustrated by video sequences from cases, case histories, audio rendering, and animations. Background information is readily available in the form of anatomic drawings, a glossary, and software and hardware help menus.

As each view and disease entity is selected, the user sees on the computer screen a simplified graphic animation, which characterizes the essential elements to be observed on the original echo image (Figs 2, 3). This serves to help the user penetrate the obscuring noise and extraneous structures on the original echo image that confuse the inexperienced observer. Rotating graphics or exploded views orient the viewer so that he or she can perceive the echo viewing plane within the context of the solid three-dimensional structure of the heart. The user interface offers quick access to any number of related information texts or alternative imaging planes. The user is thus in full control of the path through the instructional module.

This style of instruction differs radically from that of the past, since student attention and the instructional material are now better meshed. The instructional material is individualized and available when the student is in the most receptive frame of mind for learning, rather than being presented in a rigid, externally imposed path and time schedule. Compared with other teaching options, which are by nature sequential and progressive (eg, videotape), the instructional material here is offered in a nonlinear mode. The user can pursue the curriculum material in any level of detail and in any sequence, following his or her own inclination and curiosity. It can be expected that a much better psychologic match will occur between the student's receptivity toward new information and the delivery of that information, since the student proceeds at his or her own pace and can explore a unique path through the material, pausing or branching into other related information at will.

The program is designed to be visually exciting since it contains an excellently designed graphic interface and uses both complementary sound and animation on the computer screen as a way of enhancing the information displayed on the video-disk. Moreover, when a pathologic condition is presented, the student can replay normal segments and directly compare each sequence until a better understanding of the nature of the abnormality is achieved.

Hypermedia and HyperCard

HyperCard is one well-known software implementation of the hypermedia concept, but other equally attractive implementations exist (Guide [Owl International, Bellevue, Wash], Course of Action [Authorware, Minneapolis, Minn] to name a few). HyperCard is a part graphics and part data base program and includes a built-in programming language, HyperTalk (6,7). This high-level command language allows users with little or no previous experience in 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.

The central concept underlying HyperCard applications is *hypertext*. In existing hypertext applications, the user browses through a system that is designed to extensively interlink and cross-reference text and graphics in a nonlinear, interactive format that responds to the user's requests for more information on a particular subject. The project described here is one of the first in medicine, to our knowledge, to offer additional integration with audio and video material. For example, to get further information on a word or graphic, the user simply points at the area or text segment and clicks on the mouse button. The program then branches to another *card* (individual screen views, composed of multiple fields of information and electronic link points are called cards), plays a video sequence from the laser disk, calls up new text from the hard disk or CD-ROM, or in some other way immediately brings forth 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.

HyperCard contains one of a new family of computer languages: so-called object-oriented programming. In conventional programming techniques implemented in languages such as BASIC, FORTRAN, Pascal, and C, a sharp division is made between programs and data. Programs are abstract, generally applicable recipes that achieve a specific effect when a user fills in specific data for parameter values. For example, to get the record of a patient Wilson in the routine: GO_AND_FIND_ME_A_RECORD, the user would select the value WILSON for the parameter NAME; the program then executes the routine. As the program routines have general value, the structure of the data base and the records must also be fixed (or at least predictable). In object-oriented programming, (eg, LISP, Prolog, and, to some degree, HyperCard), the central issue is a concept in which data represent an instance of the concept and programs perform an action on the concept.

In HyperCard, the main concept is the card to which a *script* (ie, card-specific piece of program) and data (in the form of text or a graphic on the face of the card) are attached. Cards are organized in larger structures called *stacks*, as in "stack of cards," and contain smaller structures called button, fields, and so forth. Once a card is displayed (which is equivalent to being activated), the user may initiate other actions by selecting buttons (ie, activating the script of a button) or fields with the mouse. HyperCard allows only one card to be visible at a time, regardless of screen size. Users browse through HyperCard applications by moving between cards one at a time, much as they would flip through a stack of index cards. Cards are composed of two independent layers: a transparent foreground layer containing 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.

Unlike most conventional programming languages, the script-writing language used in HyperCard, HyperTalk, is an object-oriented language tied to the various components (buttons, textfields, cards, backgrounds) that make up a HyperCard stack. Short pieces of HyperTalk script are attached to objects in a stack and will not be executed until a specific event occurs, such as when a user selects a button with the mouse to initiate some action. All the basic HyperCard objects can be created, moved, resized, and visually restyled by choosing options from pull-down menus familiar to users of other Macintosh programs.

As a consequence, the distinction between program and data becomes blurred in object-oriented programming. Because of its structure HyperCard is immediately appealing as a simplified programming tool for the layman, since its mode of expression is similar to how humans would design a cross-referenced (multiple-choice) teaching course. The only undesirable aspect is the potential for a disorganized, nonstructural approach to the construction of the overall behavior of the program given the fact that data and portions of program (ie, scripts) are distributed over various cards.

HyperTalk as a Script-Writing Language

As defined above, the HyperTalk language interpreter within HyperCard represents a simple object-oriented language, as opposed to linear, procedural languages like BASIC, Pascal, or C. In an object-oriented language environment, nothing happens until the user (or the program somewhere) actively initiates an action on the part of the program, usually by selecting a button. "Mouse button down," "mouse button up," "new card," and "open stack" are all examples of common events occurring as a user navigates through a HyperCard application. Each of these events sends a message through the hierarchical structure of HyperCard objects. An object with a specific type of script for an event takes action when the event message is received. Otherwise, the event is passed on to the next layer, from button to card to stack, and so forth until it reaches an object that can act on that event. This capacity to pass on an action automatically implies that the actions shared by all elements in one concept can be inherited by any of the elements. For example, if the user wishes to create the button GET_OUT_ OF_PROGRAM, the user should place it at the most general of all levels, the stack.

Objects created within HyperCard exist in a hierarchy, and messages pass through the hierarchy seeking scripts aimed at controlling that event. If the user selects a button that does not contain a script with instructions to act on the "mouse button is down" event, it passes the message along to the card, the card background, the stack, and finally to HyperCard itself. Any of the objects deeper in the hierarchy may be programmed to respond to "mouse button is down." Thus, the foremost objects in the hierarchy (eg, buttons) can inherit capabilities from objects

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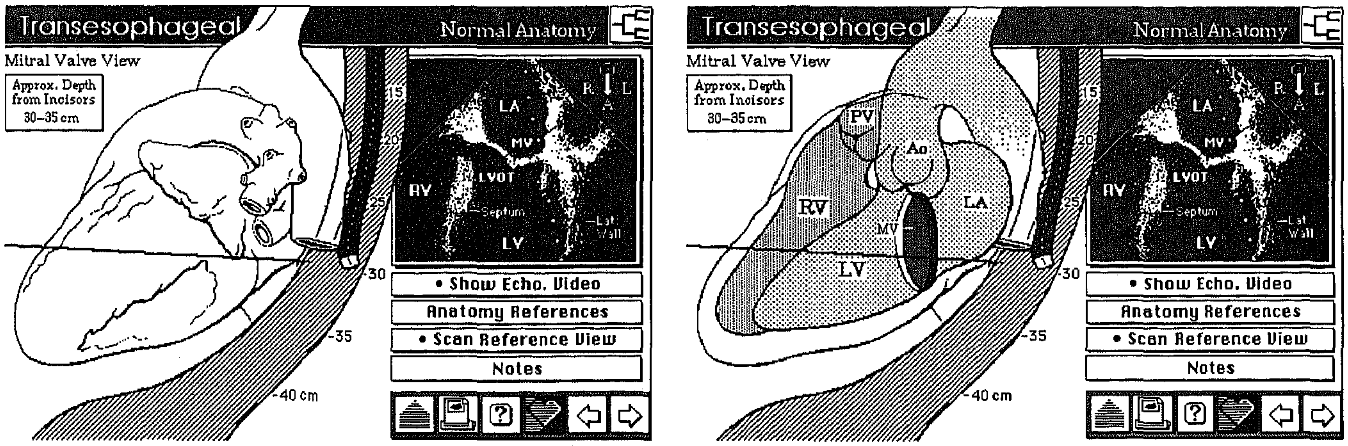
HyperTalk Script                        Notes
on mouseDown                         -- The "event" to begin action on.
   visual dissolve                   -- a visual effect for transition.
   go to card "Stenosis 0"           -- The basic navigation command
   visual dissolve                      for moving between cards.
   repeat while the mouse is down    -- starts a repeat loop that keeps
      go to card "Stenosis 1"           running as long as the mouse
      go to card "Stenosis 2"           is held down on the button.
      go to card "Stenosis 3"
      go to card "Stenosis 4"        -- "go to card..." brings up each new
      go to card "Stenosis 5"           "frame" of the animation sequence.
      go to card "Stenosis 6"
      go to card "Stenosis 7"
      go to card "Stenosis 8"
      go to card "Stenosis 9"
   end repeat                        -- ends the repeat loop.
end mouseDown                        -- ends the handler "mouseDown".
```

Figure 4. A sample of HyperTalk language, with the actual script language in the left and explanatory notes in the right column. This script operates the "Animation" button in Figure 2.

deeper along the chain (eg, card backgrounds), and large numbers of buttons on different cards can act on HyperTalk scripts attached to the card background (or stack) they all share. Scripts attached to the stack itself can control the actions of all objects on all cards within the stack. This avoids the necessity of having to attach a script to every object within a stack to tell it how to react to a specific action the user takes.

Once the object-oriented structure of the language is understood, writing scripts (HyperCard parlance for programming) in HyperTalk is comparable to using a very forgiving, English-like implementation of BASIC. HyperTalk contains a wide array of basic programming constructs for repeat loops, if-then-else and Boolean true-false logic operators, mathematical functions and operators, and text-handling routines. By using HyperTalk, the user can directly control the properties of all HyperCard objects and painting tools. Handling of variables with HyperTalk is particularly convenient, as local temporary variables may be created and used on the fly, without prior declaration. Text may be imported from text-only (ASCII format) documents or from conventional tab or comma-delimited data base and spreadsheet files, and the user can program HyperCard to accept and reformat other types of text files. The user can write custom "function" subroutines in HyperTalk script (similar in concept to Pascal functions), some of which support extensive sound and visual effects.

Figure 4 shows an example of the HyperTalk script used to control the "Animation" button shown in Figure 2. When the user holds the mouse button down while the cursor is within the "Animation" button, a short repeat loop cycles continually until the mouse button is released. This animates a sequence of draw-



a. b.

Figure 5. HyperCard allows related illustrations to be layered and revealed by the user as he or she requests more information from the program. *Here, the user holds the mouse button down over the external view of the heart in* **a** *to reveal the internal structures "underneath" in* **b**.

ings illustrating valve movement in mitral stenosis. Figure 3 shows the first four frames from the sequence. To aid the viewer's understanding of the original echo video shown on the laser disk monitor, the cardiac anatomy is simplified to mere outlines of essential features on the computer monitor. The user can simultaneously view the comparable video sequence on the videodisk monitor by selecting the "Show Echo Video" button.

In addition to the programming possibilities offered by the standard 250-word command vocabulary of HyperTalk, the native capabilities of HyperCard may be extended and customized through the addition of HyperCard words to which special-purpose segments of Pascal or C code are attached. These external commands and external functions (called XCMD or XFCN resources in HyperTalk) allow the HyperTalk language to control virtually any device with a serial interface, such as videodisk players, CD-ROM drives, and other audiovisual and computer equipment (6,7). Once a resource is installed into a HyperCard stack, its functions are typically operated with simple English-like commands such as "Video Play," "Video Step," and "Video Show."

Use of HyperCard for Medical Education

The primary virtue of HyperCard lies in its ability to easily link associated graphics, text, and video sequences into an integrated web of information. Figure 5 illustrates the use of a visual dissolve (dissolving is one of 17 visual effects built into HyperCard) from one card to another to link two different anatomic illustrations. When the student moves the cursor over the heart illustration in Figure 5a and holds the mouse button down, the external anatomy appears to melt away, revealing an illustration of the internal volumes and valves of the heart "underneath" the external view (Fig 5b). When the mouse button is released, the program dissolves back to the original external view. This allows the student to easily associate the internal structures of the heart visible in transesophageal echocardiography with the more familiar external anatomy of the heart.

The ability to create multiple levels of depth and complexity by linking illustrations in HyperCard stacks is a central strength of the program. In total, the card illustrated in Figure 5a branches directly to more than a dozen other cards (in three separate stacks) containing related anatomic graphics and animations, literature references, menu options, and program help information, and the card is linked to three different video sequences from the videodisk. Through a master menu card in another stack, the card shown in Figure 5a is indirectly linked to 14 other stacks containing approximately 180 other cards with associated graphic, text, and video information on various types of echocardiography. Carefully standardized background graphics shared by all cards present a uniformity of user interface when the user is at compatible levels in the system. These background graphics allow the user to return to the point of departure after he or she has taken a subaction and offer only a limited number of cards where changes can be made in the path through the course, thus making the process of switching from card to card largely transparent to the student user. Icons with a fixed, hence predictable, meaning that recur at the bottom of the screen allow the user to page between the previous and next cards, get in-context or general help messages, print the current screen, go to the main course menu, or exit the program directly from any card.

Clinical Experience

For the past year, this hypermedia instructional module has served as the primary introduction to echocardiography for residents completing their rotations in the cardiac imaging service at our institution. It has proved successful in providing a uniform basic curriculum in echocardiography. After 5–10 hours of independent study with this module, residents have achieved an intermediate level of expertise and need less tutoring from the attending physician than previously required. The attending physician can devote more time to conveying some of the nuances of the specialty.

A more objective, quantitative assessment of skill acquisition by means of this technique is in progress.

CONCLUSIONS

HyperCard is just one of a number of programs that implement interactive hypertext concepts in microcomputer educational applications. The mouse-driven graphic user interface of the Macintosh and Microsoft

(Windows; Redmond, Wash) operating systems have gained wide acceptance by microcomputer users. The ease with which HyperCard allows a user to redesign the graphic "look-and-feel" of interactive videodisk programs may make it an ideal tool for creating dummy test programs in the course of designing complex projects highly dependent on an intuitive, easy-to-use user interface. Hypermedia learning environments that incorporate videodisk image storage accessible by microcomputer provide a powerful instructional tool that lets electronics substitute for much more time-consuming tutorial efforts. The method offers a mechanism for enriching the image knowledge base of diagnostic specialists and could efficiently increase the number of experts. ■

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References

1. Nelson T. Computer lib/dream machines. Bellevue, Wash: Microsoft, 1987.
2. Kay AC. Computer software. Scientific American 1984; 251:53–59.
3. Engelbart DC. A conceptual framework for the augmentation of man's intellect. In: Vistas in information handling. Vol 1. London: Spartan, 1963.
4. Brunsman S, Messerly J, Lammers S. Publishers, multimedia, and interactivity. In: Ambron S, Hooper K, eds. Interactive multimedia. Bellevue, Wash: Microsoft, 1988; 273–281.
5. Cook P. Multimedia technology. In: Ambron S, Hooper K, eds. Interactive multimedia. Bellevue, Wash: Microsoft, 1988; 217–240.
6. Goodman D. The complete HyperCard handbook. New York: Bantam, 1987.
7. Williams G. HyperCard. Byte 1987; 12:109–117.