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INTERACTIVE DISPLAYS IN MEDICAL ART

Deirdre Alla McConathy and Michael Doyle
University of Illinois, Department of Biomedical Visualization and College of Medicine
Chicago and Urbana, Illinois

Medical illustration is a field of visual communication with a long history. Leonardo DaVinci, inventor, scientist, and illustrator, is perhaps the best known pioneer of medical art, but many other individuals, such as the famous anatomist Vesalius, also contributed to the development of the profession. Understandably, many factors have impacted the field throughout its growth, but the primary goal of a medical artist–to visually explain information about the health sciences–has remained unchanged. Other goals such as marketing and advertising of products are subsidiary to this central objective of presenting educational imagery to health science professionals and patients alike.

Traditional medical illustrations such as the one shown in figure 1 are static, two-dimensional, printed images—highly realistic depictions of the gross morphology of anatomical structures (Netter, 1948; Pernkopf, 1963; The Urban and Schwarzenberg Collection of Medical Illustrations Since 1896, 1977). Coincidental with technological advances in both medicine and image production, however, is the expansion of the role of medical art. Today medicine requires the visualization of structures and processes that have never before been seen. Complex three-dimensional spatial relationships require interpretation from two-dimensional diagnostic imagery. Pictures that move in real time have become clinical and research tools for physicians.

Medical artists are uniquely qualified to plan and produce visual displays for use in health communication. Basic science courses taken within a medical school curriculum prepare them to be content experts. Prerequisite life drawing, painting, color theory, graphic design and other fine art courses, and subsequent graduate coursework including anatomical drawing and surgical illustration imbue artistic skills. Using instructional design theory, artists plan goals and objectives, perform critical analyses of task and learning performance, and evaluate products and procedures. Medical artists are media technologists as well. They must choose from a plethora of media the appropriate mode of presentation for the specific content being represented. The objective in medical art is to incorporate new technologies as both production tools and modes of final presentation. The artists are therefore knowledgeable of a wide variety of media, including printed images in line, continuous tone or color; projection media such as slides, video, film, and animation; computer graphics; and three-dimensional models and simulators.

In addition to formal instruction, medical artists possess those abilities often attributed to the mystical realm of art. Perhaps because of their comprehensive knowledge base relevant to problems of visual representation, for artists an iterative problem-solving process often becomes automatic to the point of appearing to be intuitive. Previsualization of visual solutions by the artist allows exploration to occur in an effective, if not well-understood, manner. For example, Ansel Adams, renowned for his development of the zone system in black and white photography, was consciously aware of the limitations of film for representing the range of values we are able to see with the human eye. He could, however, mentally image how a landscape would be recorded by film, and thereby "see" a predictable translation to guide him. In a similar manner, medical illustrators use a combination of factual, theoretical and artistic knowledge to previsualize.

Clients and content experts need to be involved in the process of preparing visuals, but many important production decisions pertaining to the final appearance of the image are solely the domain of the artist. Artists are able to identify and manipulate many variables with predictable results and recognize the contributions of unpredictable "happy accidents."

The most fundamental decisions upon initiating a drawing involve characteristics of the light source portrayed. The importance of direction of a light source is well documented. Perceptual psychologists have demonstrated that an upper-left light source is generally the default assumption for a viewer, but direction is only one variable to be considered. Two other important considerations are color temperature and intensity, as each of these convey information about spatial relationships and can be used to invoke affective reactions. The artist sometimes needs to invent the light source, creating an unreality that is more effective than reality. For example, operating room lights provide very diffuse, even lighting of the surgical field to avoid fatigue to the surgeon's eyes; therefore photographs appear to be flat spatially. Surgical illustrators enhance the impression of space by creating an imaginary, directional light source, with strong highlights and cast shadows. Many other artistic decisions, such as viewer station point, composition, and color harmony, all impact the final results, and should be entrusted to professional communicators and qualified artists.

The medical artist embodies a link between the technical and aesthetic realms of visual communication. The skills exemplified by medical artists for the health sciences community can demonstrate an appropriate model for other fields that need to make judgments about visuals from a holistic viewpoint.

The importance of a qualified consultant and producer of visuals cannot be overemphasized. In their report to the National Science Foundation ("Visualization in Scientific Computing," McCormick, DeFanti and Brown (1987)) comment that "Because of inadequate visualization tools, users from industry, universities, medicine, and government are largely unable to comprehend the flood of data produced by contemporary sources such as supercomputers, satellites, spacecraft, and medical scanners. Today's data sources are such fire hoses of information that all we can do is warehouse the numbers they generate, and there is every indication that the number of sources will multiply." The authors suggest that interactive graphics are the best available solution to managing this information deluge. They go on to recommend that interdisciplinary teams of computer scientists, engineers, cognitive scientists, systems support personnel, and artists be enlisted to attack the visualization challenge.

One inevitable question for all types of pictorial displays is how realistic should the image be? Much debate exists as to the appropriate amount of realism necessary to include in different types of visuals. Research of the realism continuum and its effect on learning has not, however, established usable guidelines to be implemented. The current trend in educational resources is toward editing of information within pictures to a more diagrammatic style, whereas efforts to improve simulators are toward maximizing realism. Interactive displays may prove to be a reasonable solution to the editing question by providing users the flexibility of controlling the variable of realism and detail themselves. In reality, however, the issue of optimal levels of detail to include in a particular illustration is most often settled by budgetary constraints or subjective client preferences.

Medical illustrators are involved with the development of interactive visual displays for three different, but not discrete, functions: as educational materials, as clinical and research tools, and as databases of standard imagery used to produce visuals.

Health education visuals are required for a diverse audience including patients, medical students in training, and experienced surgeons. The information depicted may be factual, theoretical, abstract, or motor-skill training. Patient simulators are, for example, important methods for training manual skills because they offer the greatest breadth of learning experience with no risk of damage or discomfort to the patient. A successful simulator should provide a high degree of procedural realism. A three-dimensional model (fig. 2) used to train personnel in the procedure for fetal monitoring exemplifies a traditional type of interactive teaching display.

Monitoring a fetal heart rate during labor requires the insertion of an intra-uterine pressure catheter and the attachment of a scalp electrode to the baby. Placement of the instruments is critical since misapplication can result in devastating damage to the newborn. Correct positioning of the instruments requires the technician to palpate anatomical landmarks and visualize spatial relationships.

To satisfy these requirements in the simulator, medical sculptor Ray Evenhouse mimics soft and bony tissues with layers of synthetic materials. The structures are made from casts of bones and sculptures of soft tissues based on morphometric data. The completed simulator consists of a fetal head that is positioned within the maternal torso by an instructor in a variety of presentations. Visual and tactile realism is essential so that underlying structures such as the anterior and posterior fontanelles and facial features can be palpated to orient the trainee. In addition, the motivational factor induced by a highly aesthetic simulator contributes to the overall success of the model (Evenhouse and McConathy, 1989).

A quite different simulation is represented by an electronic textbook recently developed by Doyle (O'Morchoe and O'Morchoe, 1987) as a tool for teaching histology, the study of cell and tissue biology, to medical students (fig. 3). This prototype system operates on an IBM PC microcomputer fitted with both a high-resolution graphics display, capable of 256 on-screen colors, and a separate monochrome text display. The textbook uses the interactive digital video (IDV) interface, a device-independent process for user interaction with digital video images.

A student operating the system is presented with a menu from which a particular histological section is chosen for viewing. A realistic video image of that section is then called up from the disk and displayed on the color monitor. The student is then able to interact directly with the video image by pointing to an area of interest with a mouse and pressing a button. The system responds by displaying descriptive test on the monochrome monitor, which explains the pertinent facts about that particular image feature. For example, if the student points to a muscle cell within an image of heart tissue, the text which is displayed on the monochrome monitor explains in detail the salient morphological characteristics of cardiac muscle, how this type of muscle tissue compares to skeletal and smooth muscle, and so on. This atlas is an attempt to create an entirely intuitive user interface for the student. A specific goal was to eliminate the distraction of labeling every important histological structure on the screen simultaneously while still allowing the user instant access to the exact conceptual elaboration which he or she desires.

It is possible to reverse the above-mentioned situation so that the student can type in a structure name on the keyboard and the system then displays an image with the pertinent structure highlighted. The IDV interface can also be used to correlate one image to another so that the selection of a histological structure results in the display of either higher or lower magnification views of that particular image. This allows the student to zoom in from an orienting, low-magnification, light microscopic view, through consecutive higher-magnification images, all the way to the electron microscopic level and back again. The possibility is also being investigated of using a speech synthesizer for text output as well as a voice-recognition system for user text queries.

These examples highlight the range of possibilities for teaching with interactive visuals. The opportunities for students to learn in real time, encounter variations, self-edit information, and adopt learning strategies best suited to their own needs represent a major advancement in education.

Another burgeoning area of interactive displays involves visuals as clinical and research tools. The advent of computer technology in combination with new technologies of diagnostic imaging has provided physicians and researchers new methods of visualization.

The imaging modalities of computed transmission and emission tomography, magnetic resonance imaging and ultrasound are revolutionizing medicine. "Improved 3D visualization techniques are essential for the comprehension of complex spatial and, in some cases, temporal relationships between anatomical features within and across these imaging modalities" (Computer Graphics, 1987). For example, using the computer a plastic surgeon can modify a patient's features to simulate postoperative results. Such manipulation, based on each patient's diagnostic imagery, can be a powerful tool to help plan a surgery and also allay a patient's anxiety about the outcome. Another emerging application of computer visualization is the custom design of orthopedic reconstructions such as knee replacements through noninvasive 3D imaging.

Such developments in diagnostic imagery dictate a radical departure from conventional methods of teaching and communicating anatomical information. Medicine has traditionally relied on frontal, anterior-posterior views, but this flattened perspective is not sufficient. The explosion of diagnostic imagery has shattered conventions of orientation and requires visualization of oblique, cross-sectional and other unique viewpoints. Using computer-aided design software, students can rotate structures to improve their spatial understanding.

These major changes in spatial representation require heightened attention to fundamental aspects of preparing visuals, such as orienting the viewer. The impression of space can be enhanced by unusual oblique views, but is useful only when the user is properly oriented. Failure to establish the viewer's orientation seriously compromises the communication of the visual, yet we continue to see slides flashed with little or no orienting landmarks or graphic elements. This leaves the viewer with orientation as a first cognitive task rather than proceeding to the intended task of information processing.

Research concerning orientation and mental rotation of figures has provided a body of theory which can potentially be used to solve questions of orientation; however, application of these theories is still sorely lacking. In surgical illustration it is unclear whether it is better to depict a procedure from the surgeon's point of view during the surgery, or whether a view of the patient in anatomical position (upright, anterior-posterior orientation) is best.

Another problem that plagues visual communicators is a lack of standardization of both verbal and visual symbols. Specialty areas often develop representations that are learned by users over time, but comprehensive "dictionaries" of graphic elements would be helpful to assist the new learner and to assure consensus of interpretation.

Standardization of graphic elements would also maximize the amount of information which could be encoded into graphic symbols. For example, illustrators often employ arrows as devices for portraying the idea of direction, movement, or force. What do different types of arrows mean? In medical art there is a tendency to use simple, two-dimensional arrows to imply direction of movement. A three-dimensional arrow can also encode information about force, and can be made more or less monumental to correlate to the amount of force produced. Arrows drawn in perspectives that seem to pierce space can give information about complicated movements such as spirals or rotations. Unfortunately, no standardized vocabulary for graphic elements exists for medical art or for most specialties.

Standardization of data used to construct images would also be a boon to improving accuracy and production efficiency. At present, as each artist begins an illustration he or she must subjectively synthesize information from many resources. A database of morphometric information would assist the artist by providing measurements for an idealized form that can be manipulated, rotated, and embellished using the computer. Following the approach of human factors specialists in the design of tools and environments, the artist would have data sets of measurements to describe the range and standard for forms. Image banks would alleviate the necessity of "reinventing the wheel" (or kidney, brain, or heart in the case of medical art!) every time a new illustration is requisitioned. This way of thinking is somewhat antithetical to the traditional illustrator's mode of thinking, in which the product of artistic labor is considered to be a personal, unique interpretation of the subject matter—a problem that may impede acceptance of stock supplies of imagery.

A project that addresses the issues raised thus far is under way at the Department of Biomedical Visualization at the University of Illinois at Chicago. Aptly named The DaVinci Project, the interdisciplinary research group, consisting of experts from engineering, institutional computing, educational development, supercomputing, urban planning, architecture, medical imaging, and medical illustration, aims to create a RESOURCE CENTER FOR ANATOMICAL IMAGING. Using methods traditionally employed at a microscopic level, the DaVinci Project will establish a comprehensive, accurate description of standard human gross anatomy and its development through time, based on quantitative and qualitative data gathered from diagnostic images and actual specimens (fig. 4). Morphometric analysis and stereology will be used to develop a computer-based stereoanthropomorphic database which can be manipulated, analyzed, and enhanced for various visualization purposes. The database will benefit diverse fields including medical education, bioengineering, anatomical simulator design, forensic science, biological process simulation, surgical instrument design, pharmaceutical research and development, military technology, sports equipment design, and missing persons research.

The DaVinci Project will contribute to teaching efforts, provide a research tool to clinicians and basic scientists, serve as a production tool for artists, integrate diagnostic imagery, and utilize computer technology to standardize and visualize information. Such an endeavor summarily represents the trend toward approaching visual information interdisciplinarily, interactively, and electronically.

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Figure 1.– Traditional medical illustration by Deirdre McConathy, depicting gross morphology of a cadaver heart.

ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

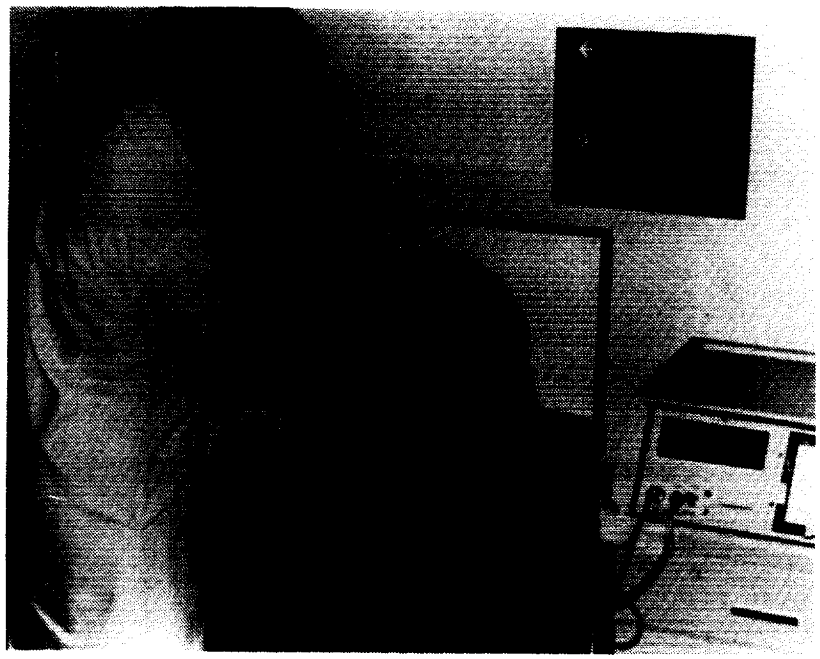

Figure 2.– Interactive patient simulator developed by Evenhouse used to teach instrumentation for fetal monitoring procedure.

Figure 3.– Electronic textbook developed by Doyle (1987) used to teach medical students about cells and tissues.

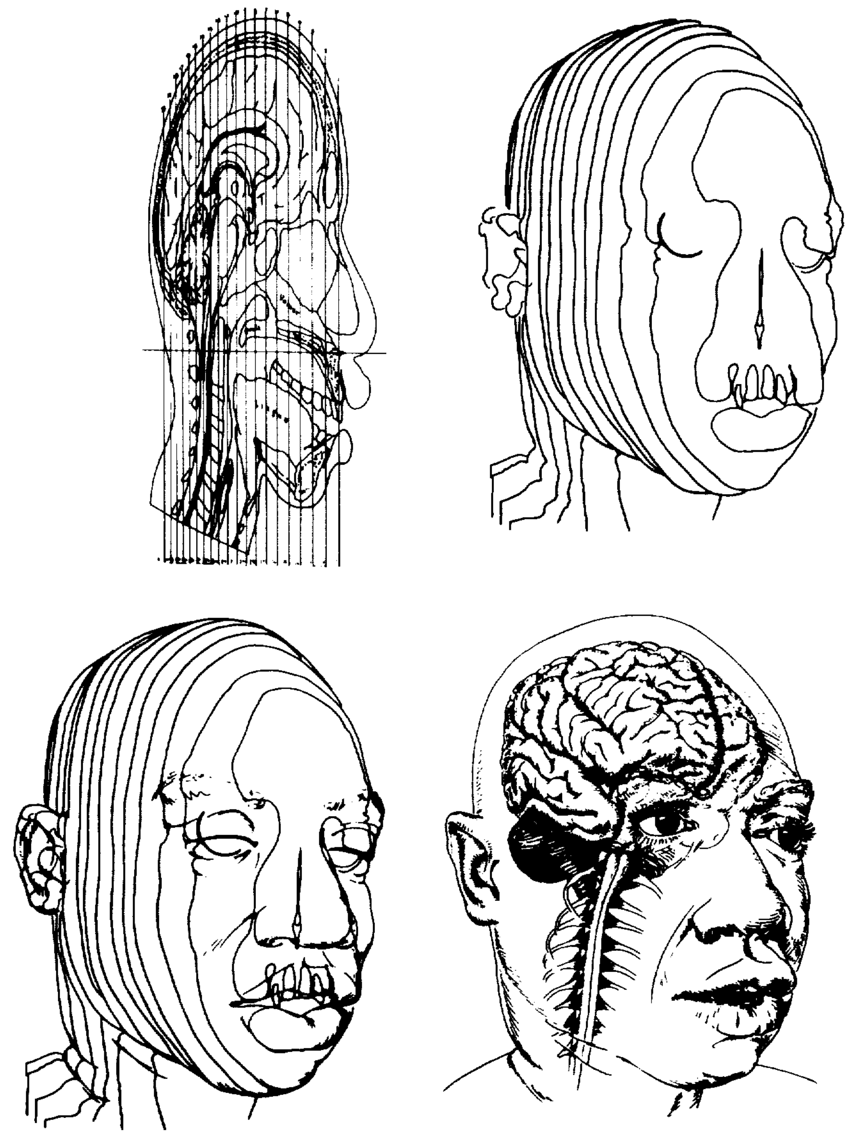

Figure 4.– Representation of the DaVinci Project's aim to use two-dimensional anatomical imaging data to produce a serially reconstructed three-dimensional computer database of standard anatomy.