A Computerized Three-Dimensional Atlas of the Human Skull and Brain

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Any sufficiently advanced technology is indistinguishable from magic.—Arthur C. Clarke

In this issue, Tiede et al (1) describe in text and still photographs their computer software, which must be experienced in person to be fully appreciated. Attendees of the InfoRAD section of RSNA '91 who permanently ringed the authors' exhibit had the opportunity to do just that. They weren't just looking at a real-time interactive atlas of neuroanatomy and neuroradiology, capable of displaying structural and functional information on each of millions of voxels, with a full-blown three-dimensional ray-tracing module thrown in for good measure. They weren't just peering through the looking-glass monitor screen as a solid-modeled human head rotated in space, shedding layer after layer of color-coded anatomy at the user's whim. They were looking into the future.

Most of the work of software engineers goes unnoticed and unappreciated. The artisans of the information age shape data with tools of logic. Few give much thought to their progeny: gizmos that control our automobile fuel injectors, navigate our airliners, tally our grocery store purchases, and reconstruct our magnetic resonance images. Hackers occasionally bestow upon a well-written software program the status of "neat hack" or "elegant code." Only rarely does a program so transfix the user that he or she stops trying to discover how they did that and falls under the spell of the illusion. That's magic.

What does magic have to do with neuroanatomy and neuroradiology education? Readers of this journal understand the three-dimensional relationships between neuroanatomic structures after having viewed thousands of clinical neuroimaging studies. Our younger colleagues in medical schools, residencies, and fellowships have no such fund of experience. They plod through the same inept dissections and agonize over the same exaggerated artists' renderings and oxidized jar specimens that have constituted neuroanatomic education for decades. They are ridiculed by staff members when they mistake the sylvian fissure on computed tomography scans for a middle cerebral artery infarct. The generation weaned on the instant gratification of video is a natural target for interactive educational techniques.

Computers have been used as aids to medical education for over 20 years (2). The original efforts in this area involved text-based tutorials, often embellished with crude on-screen line drawings or linked to slide projectors. Computer-controlled multimedia techniques for anatomy and radiology education are more recent developments. These programs typically consist of hundreds of snippets of text, cleverly linked together and spiced up with examination questions, sounds, and images both static and dynamic. Images are displayed directly on the computer monitor, or on an external monitor linked to a videodisc player (3–5). Unfortunately, the images and movies usually cannot be viewed from different angles, sliced, or otherwise explored in real-time. Three-dimensional computer images are typically prerendered from a set viewpoint.

Like computer-aided instruction, computer imaging techniques continue to advance. Rendering computed tomography, magnetic resonance, and positron emission tomography data sets and digitized cadaver sections in three dimensions continues to be an active area of academic and industrial research (6–12). Three-dimensional imaging is finding use in clinical practice and medical education. Medical illustrators have traditionally played an important role in the depiction of complex three-dimensional anatomic relationships. The artist's palette is becoming increas-

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ingly digital. Computer graphics most commonly replace ink for generating line drawings (13). Some computer-generated illustrations use gray-scale gradients to simulate shadows. In the future, the illustrator's job will incorporate elements of film production, as three-dimensional computer atlases are manipulated to emphasize topics of interest. To create shadow, the illustrator will no longer need to laboriously render it. Instead, one could simply select "create new light source" from the command menu. The ability to incorporate "movies" of virtual anatomic dissections (14) into medical publications will become reality when software such as this becomes available to the end-user.

The magic accomplished by Tiede et al (1) is that they have fused elements from the three-dimensional imaging and education disciplines to create a "virtual" human head cadaver capable of endless nondestructive dissections. The ability to glean structural and functional information for any voxel of choice, regardless of viewpoint, is unparalleled. The ability to see in three dimensions the individual structures responsible for each line on a simulated radiograph is similarly unique.

So what's the point? The medium is the message, and a print medium such as this journal is inadequate for relating the message. The magic has to be experienced personally.

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