Simulation and new learning technologies

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SUMMARY Changes in medicalpractice that limitpatient availability and instructors' time have resulted in poor physical diagnosis skills by learners at all levels. Advanced simulation technology, includingthe use of sophisticated multimedia computer systems, helps to address this problem. For many years 'Harvey', thé Cardiology Patient Simulator, and thé UMedic Multimédia Computer system have proven to be effective tools to teach and assess bedside cardiovascular skills when they are integrated into thé required curriculum of medical school and postgraduate training. In thé future, virtual reality technology, based initially on data front thé Visible Human Data set, will provide thé majority of simulation-based training. Models that provide a high level of visualfidelity and use sophisticated haptic devices that simulate thé `touch'and feel'of a procédure or examination are now being used in selected medical centers. The présence of these tools is not enough. Evidence-based outcomes must show these systems to be effective instruments for teaching and assessment, and medical educators must be willing to effect change in medical educatign to ensure thé appropriate use of these systems in thé next millennium.

Introduction

In thé past century, there bas been an exponential growth in our knowledge of thé human body, its structures, its funcdons, what can go wrong with it and why. The major advances in diagnostic tests and imaging have been truly remarkable and, along with our ability to prevent or cure illness and prolong active life, have had a major impact on thé quality of thé human condition. Over thé past few décades, medical educators have been quick to embrace new technologies and pedagogical approaches such as informatics, problem-based learning and just-in-tinte learning in an effort to help students deal with thé problem of thé growing information overload.

Medical knowledge, however, bas advanced more rapidly than medical éducation. Even as we unravel thé génome and begin thé era of proteomics, we use outdated and often ineffective methods to teach skills and mold attitudes. Fortunately, positive changes are on thé horizon for medical educators. Rapid advances in technology will lead to a révolution in thé teaching of both basic clinical skills and thé manual skills necessary to perform invasive procédures and surgical interventions. Simulation technologies are available today chat have a positive impact on thé acquisition and retention of clinical skills. Virtual reality in particular is playing an increasing role in thé skills training of healthcare professionals. It is likely that medical éducation in 2020 will differ greatly front medical éducation in 2000, though one must keep in mind thé old, and probably apocryphal, Chinese proverb: "To prophesy is not easy. Particularly in regard to thé future."

Current problems in medical skills training: a common scénario

Peter Smith, a senior medical student, exited thé OSCE station with his preceptor and felt he had made thé correct diagnosis and initial treatment plan regarding his 72 year-old patient with exertional angina pectoris: unstable angina secondary to coronary artery disease to be confirmed by an exercise stress test. To his surprise and disappointment, he was notified that his patient's exertional angina was thé result of critical aortic stenosis, a diagnosis he missed by not appreciating thé long systolic murmur at thé patient's upper right sternal edge. Worse, thé patient would be at risk for sudden cardiac death if he were to undergo exercise stress testing. Despite his disappointment, Peter was relieved to learn that he would still pass and graduate from medical school.

Over thé next few days, Peter reflected on thé OSCE encourlter and wondered how he, a graduating medical student, had missed an important bedside finding. He was upset with himself for not eliciting thé finding, but then reflected on thé adequacy of his medical-school training in auscultatory skills.

Skills training during preclinical years

After each of his first two years of medical school, Mr Smith underwent an assessment of his ability to perform a complete physical examination. However, during each of these sessions, he really went `thoough thé motions' of thé exam and was not tested on his ability to elicit a specific finding. He learned about thé physical findings of aortic valve stenosis from a textbook rather chan from personal expérience. During his first 2 years of medical school, his mentors seemed unconcerned about his inability to perform a detailed, organ-specific physical examination since he and his classmates were never graded on their clinical skills (Kassebaum & Eaglen, 1999).

Skips training during clinical years

During his thirdyear clinical clerkships, Mr Smith spent more time in conférence rooms, discussing patient care or

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related journal articles with the ward team, than he did at patients' bedsides honing his skills (Shankel & Mazzaferri, 1986). When the ward team did visit a patient with an important physical finding, there was limited time to practice his exam skills (Collins *et al.,* 1978).This resulted from:

- occasional reluctance or embarrassment of patients to expose themselves to the large number of individuals on the ward team;
- impatience of team residents eager to conclude rounds quickly in order to attend afternoon clinic;
- impatience of attendings eager to conclude rounds quickly in order to attend a privatepatient clinic or meeting, perform a procedure or experiment, etc.;
- difficulty locating patients undergoing diagnostic tests;
- rapid patient discharges due to efficient managed-care caseworkers.

Peter was aware of the availability of CD-ROMs and tapes of heart murmurs in the library. However, these were optional resources with content that was never required or tested. He knew of students at other schools that had these types of resources as part of their core curriculum and wondered whether they were better skilled than he. Peter realized that in a few months he would be seeing patients on his own who may also have important auscultatory findings. He further worried, if his auscultatory skills suffered, what about his ability to perform a competent neurologic or ophthalmologic examination? Why did those in charge of his medical education not make sure he possessed the skills necessary to be a physician before allowing him to graduate? Unfortunately for Peter, deficiencies in die performance of clinical skills are not limited to medical students; they are also prescrit among residents in internal medicine (Mangione & Nieman, 1997; St Clair *et al.,* 1992), emergency medicine (Jones *et al.,* 1997), and pediatrics (Gaskin *et al.,* 2000).

Simulation technology in the core curriculum: a potentiel solution

The above fictitious case *highlights* many of the problems occurring in academic medical centers today as a result of reduced physician teaching time and reduced availability of patients as educational resources. The increased use of simulation technology to supplement skills training with repetitious, standardized training would appear to be a logical solution to the problem. Despite the widespread availability of simulation technology, however, its use has not yet become part of the cote curriculum at most medical schools. This may soon change, regardless of the opinions of individual faculty and medical educators. Several key organizations have recognized the role of simulation technology in medical education and have recently implemented guidelines or programs to foster its development. The members of the Medical School Objectives Project, sponsored by the Association of American Medical Colleges, stated in their Medical Informatics Objectives chat "the successful medical school graduate should be able to . . . effectively utilize various computer-based instructional (and self-assessment) tools, including electronic tutorials and patient simulations" (Medical School Objectives Writing Group, 1998). The American Board of Intemal Medicine shares this view as reflected in its decision to form the Physical Examination Self-Evaluation Process Committee. This committee bas developed a multimedia computer-based, self-assessment program focusing on "physical examination and physical diagnosis skills" (Norcini, 1993).

Physical body simulators

Simulators now available and routinely used in medical education vary in their complexity and ability to represent real-patient situations. Some models permit examination and manipulation by the student, but do not respond or provide feedback. Others are more sophisticated and interact with die students.The simplest simulators resemble a person in size and weight only, much like a mannequin in a department store. Tbese types of simulators are used extensively in trauma cases to replicate automobile accident victims. Learners use these simulators to practice cervical-coller placement, removal of patients from automobiles, and other ways to stabilize accident victims.These simulators typically have permanent and non-modifiable `injuries' such as head lacerations and contusions, a dilated pupil, or compound leg fractures. Any sense of realism is due to the scenario rather than the simulator itself. The simulator does not respond to any action and its sole requirement is to represent a 'body', i.e. to be the approximate size and weight of a typical person.

Anatomic-pathologic simulators

Another type of simulator is the simple anatomical model used to train students how to perform a single component of the physical examination. Exemples include models for breast examination, eye examination, car examination, female pelvic examination and male rectal examination. The advantage of such simulators is chat they enable teaching on a practical level without any imposition on real patients, especially with sensitive topics such as pelvic examination. When using simulators of **lower fidelity it is important to appreciate their limitations and use them in situations that maximize their strengths (Macintosh** and Chard, 1997).

Procedural skills simulators

Other simulators are used to learn, practice and assess procedural and practical skills.These simulators are currently used to train learners in the following techniques:

- intravenous access via cannula insertion and surgical cut down;
- catheterization of the male and female bladder;
- airway management, including intubation (some of these devices, including the Cricothyrotomy Simulator [Armstrong Medical Industries, Inc., Uncolnshire, IL] allow the learner to practice catheter oxygenation/jet ventilation via the cricothyroid membrane in cases of laryngeal, pharyngeal, lingual tonsilar and epiglottic pathology; this is important because die clinical opportunities for employing this kind of technique are otherwise rare);
- soft tissue injection and aspiration of knee, shoulder, elbow and wrist joints;
- ureteroscopy for practice of kidney stone removal.

Surgical simulators

Surgical training is one area that seems ideally suited for the use of simulators. Proficiency in surgery requires knowledge of underlying anatomy, dexterity and frequent practice. Despite this apparent fit, there have not been many valid studies examining thé use of simulators for surgical training. Simulators are currently available to train learners in thé following surgical techniques:

- simple wound closure, evaluating suture tension and accuracy of placement;
- bowel anastomosis (closure), using sutures and staples;
- laparotomy;
- episiotomy and theed-degree tear of thé perineum (with ability to practice suture repair at multiple levels);
- toe surgery, including including ring block with local anesthesia and wedge resection of thé nail bed and total ablation of thé nail;
- dermatologic surgery, including cutting, suturing, and removal of sebaceous cysts, lipomas,perianal hematomas, and skin tags.

Harvey, thé cardiology patient simulator

Harvey is a teaching device that provides a comprehensive cardiology curriculum by realistically simulatiog 27 common and rare cardiac conditions. The physical findings programmed in Harvey for each disease include blood pressure, bilateral jugular venous pulses, bilateral carotid and peripheral arterial pulses, precordial impulses in six différent areas and ausçultatoryy events. The latter are heard in thé four classic auscultatory areas, are synchronized with thé pulses and vary with respiration when appropriate.

Harveyhas been subjected to rigorous testing to establish its educational efiicacy.The most comprehensive evaluation of any simulation technology was thé multicenter study of Harvey sponsored by thé National Heart, Lung, and Blood Institute. (Ewy *et al.,* 1987). It involved 208 senior medical students at five medical schools. Fourth-year medical students who used thé Cardiology Patient Simulator (CPS) during their cardiology elective performed significandy better than thé non-CPS-trained group, who learned in thé traditional manner from real patients. This was true not only on thé CPS skills post-test ($p < 0.001$), but also on thé live patient skills post-test ($p < 0.03$). In addition, there was no statistically significant différence in thé way patients perceived thé professional behavior of CPS-trained and non-CPS-trained students. The latter data address thé concern chat simulators may negatively impact physician behavior. In another study involving more than 200 second-year medical students at thé University of Michigan, incorporation of Harvey into a required physical skills course significantly improved overall cardiac examination skills as measured by pré- and post-tests of unknown findings on thé simulator ($p < 0.001$) (Wooliscroft *et al.,* 1987).

In addition to its use as an educational cool, Harvey has been used as a systematic and objective tool for testing bedside cardiovascular examination skills (Ewy *et al.,* 1987; Jones *et al.,* 1997; Wooliscroft *et al.,* 1987; Gaskin *et al.,* 2000). Testing with simulators such as Harvey is actually more effective than testing with actual patients. With a simulator, there is complete control over thé specific task selected, e.g. a bedside cardiac exam, as well as thé complexity of thé task. Exact validation of `patient' findings leads to a standardized and more-objective skills-testing process.The proven value of`Harvey' as an educational tool has resulted in thé recent suggestion by die American College of Cardiology Task Force on Education (Gregoratos and Miller, 1999) Chat 'Harvey' should be integrated into thé day-to-day teaching of clinical cardiology.

Computer-aided instruction: CD-ROM-based software

Computer-aided instruction (CAI) appears to be an ideal method for teaching a cote of material repetitively. CAI programs allow for an interactive educational process, requiring active involvement by thé student or house off cet in thé learning process. In addition, thé students are able to run thé programs individually, at cimes convenient to them without thé need for direct faculty supervision. Currendy, there are hundreds of CAI CD-ROM programs available for learners at all levels in many areas of interest. These include programs that teach radiology and ECG interpréta-tion, advanced cardiac life support, procedure skills and physical diagnosis techniques.

UMedic, Multimedia Computer System (MCS)

The UMedic MCS has been developed over thé last 15 years with multimedia features chat include computer and video graphics and réal-cime digitized video and audio. Fifteen patient-centered case based programs comprise a comprehensive generalist curriculum in cardiology. Its structure and content have been described elsewhere (Waugh et al., 1995; Issenberg, McGaghie *et al.,* 1999).

A recent multicenter study demonstrated chat UMedic could be integrated into thé entire four-year medical school curriculum (Petrusa *et al.,* 1999). A total of 1586 students at six medical schools completed 6131 programs and rated thé educational value of thé system favorably compared with other learningmaterials.The study resulted in a recommended four-year curriculum plan for thé UMedic system. Valid pré- and post-tests were then created to measure outcomes in bedside skills (Issenberg *et al.,* 1998) and were used in an additional multicenter cohort study involving senior medical students at five institutions that compared thé UMedic system with traditional methods for teaching bedside skills in cardiology (Issenberg, Petrusa *et al.,* 1999). In thé intervention group, UMedic modules replaced instruction in bedside skills that occurred during teaching rounds and individual patient work-ups. There was a statistically significant improvement in thé pré- to post-test scores of thé UMedic trained students compared with non-UMedic students ($p < 0.001$). Similar results occurred in a similar recent study involving second- and theed-year internal medicine residents (Issenberg *et al.,* 2000).

The most successful application of UMedic has been in its combined use with Harvey. In this way, thé learner has thé benefit of a large `patient pool' on which to practice bedside skills along with a multimedia teaching program that provides `live' faculty presentations and feedback in an interactive format. While this type of learning now Cakes place in defined areas such as clinical skills or learning resource centers, future systems will use more advanced technology to enable universal access at any time and place to chose who wish to learn or need to be tested. Undoubtedly, **there systems will incorporate thé use of virtual reality.**

Virtualreality

Virtual reality (VR) is a concept that is intumately familiar and intuitively obvious to children as a consequence of video-game technology but which is far less familiar to adults who teach and practice medicine. Its roots are in the branch of computer science dedicated to artificial intelligence. At its simplest, virtual reality bas been defined as, "an artificial environment which is experienced through sensory stimuli provided by a computer and in which one's actions partially determine what happens in the environmenC (*Merriam Webster Collegiate Dictionary, 1996).*

Invasive procedures: 'See one, do one, teach one'

Teaching learners how to perform invasive medical procedures and assessing their performance is a challenging task.Traditionally, learners have observed more experienced physicians performing a procedure. After a brief apprenticeship, supplemented by reading textbooks and occasional practice on cadavers, the learner is then allowed to begin doing portions of the procedure on patients under the tutelage of the mentor. This process is inefficient and inevitably leads to considerable anxiety on the part of die learner, die mentor and at times even the patient.

Thoracentesis, for example, is a common and relatively straightforward procedure in which a needle is passed through the chest cavity to allow drainage of pleural fluid surrounding the long for diagnostic and/or therapeutic purposes. Typically, a second-year medicine resident will demonstrate the procedure for a first-year resident with the implied promise that the next time a patient on their service requires the procedure, the first-year resident will perform it with the second-year resident 'talking him or her through it'. Inevitably, after performing the procedure once or twice himself, the inexperienced teach the even more inexperienced, leading to the medical adage, 'sec one, do one, teach one'.

Invasive procedures are difficult to learn because they require an understanding of complex these-dimensional anatomy and tactile skills for the manipulation of a probe (needle, scope, catheter, surgical instrument, bioptome, etc.), commonly referred to as acquiring the 'feel' for the performance of the procedure (Robb, 2000). 'Mis inherent complexity inevitably leads to a high complication rate and steep learning curve.

As students complete their formal training and enter practice, medical centers will require that they be 'credentialed' to perform a variety of procedures. Usually this requires documentation that the physician has performed a minimum number of procedures, die lirait having been set in some cases by national professional bodies and in others by the local medical center credentials committee, and a written statement from the training director of the institution from which die practitioner bas come certifying his/her competence to perform the procedure. For the most part such statements are qualitative; only in rare instances are they based on objective measures of assessment.

When learning to perform an invasive procedure, the learner must simultaneously correlate the clinical assessment of an ill-and possibly sedated-patient, manipulation of a probe or surgical instrument, and the these-dimensional interpretation of a two-dimensional imaging study, all the while assessing physiology or performing a therapeutic procedure. In the beginning, most learners are able to focus only on one or two of these components at a time, contributing to both risk and stress.

Virtual reality simulation systems allow learners to practice the procedure a portion at a time, without risk to a patient. These systems, if validated, could potentially also be used to assess the learners skills for certification of competence (boards, hospital credentialing, etc.) and for maintenance of skills or acquisition of new techniques once in practice.

Computer-based anatomic models

For the last decade, computer based volume renderings of the whole body and specific organs have been generated. Initial efforts used the Visible Human Project (VHP) data set, a databank of high-resolution digital anatomy of both men and women, available from the National Ubrary of Medicine (Visible Human Project, *1999).* First implemented in *1994,* the VHP bas given researchers access to data in multiple modalities, including X-ray-based computed tomography (CT) and magnetic resonance imaging (MRI). These anatomic models are remarkably lifelike, and demonstrate realistic surface textures.

Virtual endoscopy

Simply viewing the surface of an anatomic model, although visually pleasing in an artistic sense, accomplishes little. Physicians wish to look inside the body, a concept first dramatized in the *1966* movie *Fantastic Voyage (Fantastic Voyage, 1966).* In that movie a physician suspected foul play when a diplomat became ill. He introduced a miniaturized submarine into die diplomat's body to make a diagnosis. In the 21st century virtual endoscopy systems allow the learner to see examples of normal patients and those with disease so that the student is able to anticipate how tissues will appear at the actual physical endoscopy. If the patient model is constructed using graphical data from an actual patient's imaging data (CT/MRI, etc.), die virtual endoscopy bas the potential to replace the invasive procedure for diagnosis. And if die procedure to be performed is therapeutic, one could rehearse the therapeutic procedure on a VR Smulator prior to performing the identical procedure on the patient. This would be of particular value when unusual or particularly challenging cases are encountered.

In many instances only the spatial or surface characteristics of pathology are required (e.g. ulcer, coronary obstruction, etc.), but virtual techniques currently cannot replace physical biopsy when pathological examination of tissue is required (Blezek & Robb, *1997).* This may change in the near future. Characterization of tissues by MRI, ultrasound and other techniques is progressing rapidly (Satava & Robb, *1997).* Benign tissues may be differentiated from malignant ones in the future based on their surface characteristics as assessed by MRI.

Touch, feel and haptics

Haptics, the study of touch, allows the incorporation of **tactile stimuli** into VR systems allowing the learner to obtain the `feel' of an invasive procedure (Blezek & Robb, 1999). It is generally agreed that this is the most difficult part of teaching an invasive procedure and that improvements in this area of instruction have the potential to steepen the learning curve and improve patient safety. Haptic-force feedback devices, the simplest of which is the joystick, are commercially available (Massie, 1996).

To illustrate die use of such devices, consider die difficulty of teaching a learner to perform deep nerve block techniques. The delivery of local anesthetics to the spinal nerves or die deep plexuses, such as die celiac, for relief of pain is the epitome of the learner having to get die `feel'. The teacher demonstrates and explains that as the needle passes through skin one feels a `pop' as the resistance of the skin is overcome. Passage of the needle through the paraspinal muscles engenders less resistance. One bas to be careful not to strike either die kidney which would feel `firm' or the vertebrae which would be `hard'. As the needle approaches the descending thoracic aorta the `pulsations' can be felt on the tip of the needle which is tien directed away toward die celiac plexus.

If one mounts a force transducer on a needle and passes it through the unembalmed tissues of a cadaver on the saure path discussed above, one can direcdy measure the force required to overcome the resistance of each structure. Delivering those sequential forces to the learner using die force-feedback device, a virtual needle, allows die learner to experience how passage of the needle into a patient feels (Martin *et al.,* 1999). Others have calculated die relative densifies of tissues using the Houndsfield units from CT scans and tien have assigned relative forces to various tissues to achieve the saure end (Satava & Jones, 1999).

Current state-of-the-artvirtual simulators

Initial VR simulation systems were crude, but improved rapidly as the speed and capacity of computers increased. These newer systems, while much more realistic in simulating die experience, were prohibitive at most medical centers because of their high cost. Recently, a more affordable VR simulator was developed to provide multiple uses in a single unit. 'Me Pre0p Endoscopic Simulator (HT Medical Systems, Gaithersberg, MD) is a realistic training simulation system that integrates force feedback, multimedia, and 3D graphics on a personal computer (Tasto *et al., 2000).*

The Pre0p simulator comprises a computer, a display monitor and an AccuTouch Endoscopic Interface Device that consists of a proxy endoscope that looks like a real endoscope and is electrically connected to the second part of the interface device, a robotic mannequin into which die endoscope can be inserted. Various sensors track the state of the system and send this information back to die host computer. The simulation uses this information to compute appropriate visual and tactile responses to the motions imparted by the user. These responses are transmitted to the user through visual, audio and haptic modalities, creating die illusion for the user that he/she is insertiog the endoscope into a real patient. The robotic mannequin has been designed to accept proxy bronchoscopes, sigmoidoscopes, colonoscopes, gastroscopes and ureteroscopes through the appropriate anatomic models.Tracking of scope motions is achieved with sensors that monitor insertion and rotation of the scope tube, while electrical actuators provide translational and/or rotational force feedback based on the state of the endoscopy simulation.

Initial results of studies to assess the effectiveness of this system in simulating bronchoscopy have shown that the device can differentiate experts (defined as individuals who performed over *500* bronchoscopies) from those with intermediate experience (defined as individuals who performed more than *25* bronchoscopies but fewer than *25)* or beginners (defined as individuals with no experience in performing a bronchoscopy) (Mehta *et al., 2000).* Experts performed the procedure in a significandy shorter period of time and with fewer mistakes (e.g. `collisions' of scope against mucosa wall) than the intermediate and beginner groups.

In an era where the numbers of skilled teachers are declining and pressures to increase patient volumes are increasing, fewer mentors are available. VR simulation systems have die potential to greatly improve the training of learners at all levels in various fields of medicine. The saure technology that simulates a bronchoscopy can bc used to simulate an ophthalmologic, neurologic or cardiovascular physical examination. The potentiaI advantage of these systems compared with die current method for testing and certification, including written and oral examinations, is that they allow die examinee to demonstrate clinical skills in a controlled clinical environment while still exhibiting cognitive and language skills (Gaba *et al.,* 1998).

Discussion

Despite the availability of devices with advanced simulation technology designed specifically for the instruction and assessment of medical students and physicians, too many medical schools fail to employ such devices to teach and evaluate learners' skills (Kassebaum & Eaglen, 1999). The presence of these tools is not enough. Evidence-based outcomes must guide medical educators who are willing to effectchange.

In an article in the End-of-the-Millennium Special Issue of *Scientific American,* entitled 'The Unexpected Science to Come', Sir John Maddox wrote, "The most important discoveries of the next *50* years are likely to be ones of which we cannot now even conceive" (Maddox, 1999). Foreseeing what new technologies will be in use in the year *2020,* far less predicting their impact on the day-to-day practice of medicine and its teaching, is an exercise fraught with danger. The compilation of essays by the Pulitzer Prize-winning Richard Rhodes, entided `Visions of Technology', is replete with examples of predictions that, in retrospect, missed the mark significandy. Some predictions, however, are remarkably prescient. One essay points out that, over the past 100 years, die technological status of die world as a whole advanced at a roughly exponential rate, doubling every *20* years (Rhodes, 1999).

Four general predictions may be offered on the impact of simulation and virtual reality technology on the practice of medicine and medical education in *2020:*

(1) Anything to do with the human body in sickness and in health that is `digitizable'-and thus `storable', `manipulable', `clonable' and `transmissible'-will be, and the computers involved will become faster, smaller and cheaper.

(2) The présence of such stored `medical avatars', whether originally created for diagnostic purposes or teaching purposes, will allow for virtual-reality learning expéri ences customized for thé individual trainee for a specific case.
(3) Simulation technology is unlikely to have a major impact on thé training of history taking, and, unless we take appropriate steps to prevent it, any effect on thé promo tion of appropriate attitudes is more likely to be néga-tive than positive.
(4) The major impact of such technologies will be on skills training through their ability to provide on-demand access to `deliberate practice'.

Skills may be defined as "actions (and reactions) which an individual performs in a competent way in order to achieve a goal" (Ericsson, 1996). One may have no skill, some skill or complete skill.Therefore,when teaching or testing a skill, thé level of acceptable mastery musc be defined depending on thé training level. Ericsson has demonstrated that, in competitive performance domains such as athletics, music and chess, thé différences between individuals, from novice to champion, "are among thé largest reproducible différ-ences in performance observed for normal adults". He also suggests that similar large différences would be expected in other domains of expertise (including medicine), in which there is a long period of education followed by an apprentice-ship.

The most important identifiable factor separating thé elite performer of skills from **others is thé amount of `deliber-ate practice'.This includes practice undertaken over** a long period of time in order to attain excellence, as well as thé amount of ongoing effort required to maintain it. Deliberate practice has been defined as thé opportunity to tackle "a well-defined task with an appropriate difficulty level for thé particular individual, informative feedback, and opportuni-ties for repetition and corrections of errors" (Ericsson *et al.,* 1993).

In thé early part of thé last century, Sir William Osler wrote, "Thé art of medicine is to be learned only by expéri-ence, `tis not an inheritance; it cannot be revealed. Learn to sec, learn to hear, learn to feel, learn to smell, and know that by practice alone can you become expert" (Osier, 1919).

However, it is well known Chat, during both undergraduate and postgraduate medical training, there is an inherent capriciousness in regard to opportunities to gain deliberate practice in learning new skills or honing old ones. Even when opportunities to practice specific skills do occur, there is often no `informative feedback or opportunities for repeti-tion or correction'. Thé problem in medical éducation is that thé subjects necessary to `deliberately practice upon' are human beings, with all their diversity and variability.

Simulations and virtual reality hold out thé promise of unlirnited access to deliberate practice as part of skills training. As thé skills required for thé practice of invasive medicine become more numerous and more complex, such access to practice and rehearsal will become more essential.

Technology and medical education: what does thé future hold?

The year 2020 seems such a long time away, yet 1980 seems just a short time ago! When learning from thé past to predict thé future of medical education, one thing is sure-medical educators are not `early adopters'. It took 30 years for problem-based learning (PBL) to truly become mainstream in thé field. The need to inculcate a culture of lifelong learning is more talked about than practiced, and some medical educators still think that OSCE is an organization of oil-producing nations. So we will take thé easy way out in compiling our prédictions regarding thé impact of technology on thé future face of medical education. Although we use thé word `will' in making thé following predictions, we are, in truth, realIy suggesting what *should* happen.

The undergraduate curriculum will be unrecognizable in thé traditionaI sense since thé stages will be marked less by organ/system or discipline-based blocks or rota-tions, and more by thé attainment of measurable outcomes, thé rate of which will vary from student to student. The merging of educational strategies such as PBL and self-directed learning with thé just-indîne availability of information through IT and thé use of cumulative learning portfolios of practical and clinical experiences as a major assessment cool will allow, within limits, students to progress through thé curriculum at their own pace.
(2) Increasingly, in thé early years, thé acquisition of knowledge and understanding will be through self-directed (but outcomes driven) learning. Information to facilitate that learning will be delivered over thé Internet, using fast broadband `pipes' to transmit text, audio, video, chat groups and, where appropriate for understanding, simulations and virtual reality. All of this will be enhanced by live group discussion and tutor input.
(3) Realizing that, despite regional, national and international différences in core curriculum content, there are overlapping commonalities, a growing amount of thé learning material required for core learning will be shared between medical schools and delivered over thé Internet. In some cases, these would be single learning items such as texts and interactive simulations. In other cases, whole modules or even blocks will be used communally.
(4) In thé later years, cumulative electronic learning portfolios will map each individual students progress in meeting thé learning outcomes. They will ensure that all students are exposed to patients illustrating thé key common problems faced by primary-care physicians and that thé students have seen thé `prototype' cases around which clinical problem solving is based. **Appropriate use of these learning portfolios will also ensure that thé underlying anatomical** and pathophysi-ological concepts are reinforced as clinical cases are encountered. This will require more basic science input into thé later years of thé curriculum.
(5) Simulators and simulations will become more software than hardware, i.e. more virtual reality than real.
(6) The réal power of VR simulations is their potential widespread accessibility. Simulations, with all their inter-activity, will be widely available over thé Internet. For many, thé limiting factor will be thé availability of thé hardware `front end'-thé controls that allow thé operator to interact appropriately with thé simulation. For some simulations a standardized front end will be

thé norm, as gaming joysticks and ports have become. For thé more complex procedures special hardware will be necessary. Such hardware will be relatively inexpensive and can and should be scattered around clinical facilities and accessible round thé clock so that on-demand skills training, rehearsal or updating is available. In some cases, thé hardware may be inexpensive enough to be purchased by individuals, allowing them to deliberately practice or rehearse anywhere they avant even at home with thé kids. Regular upgrading of thé skills appropriate to their practice using simulators will be a normal part of continuing professional development (i.e. continuing medical education, or CME)-even for those practicing in thé community.

And finally, do not forget gaming and thé gamers, who, more than any other group, brought simulations into thé mainstream. If there is any challenge to their manual and décision-making skills out there, they will avant to try it and compete with others. And there will be someone out there who will avant to sell it to them. Look to see many complex surgicaVprocedural simulations available in game arcades and even at home. Medical simulations will be seen as thé ultimate game. Just think about it: some 15 year-0Id challenging a cardiac surgeon in a by-pass operation simulation-and winning! It is inevitable, and may be appropriately humiliating.

Conclusion

There are those who will see thé future elucidated above as an Orwellian nightmare of technology's dehumanizing face. They will see only a dark picture of chips, bits, bytes, pixels and avatars obscuring thé human tragedy of illness and disease and thé anguish they cause. But they will be wrong.

Doctors better trained in basic clinical skills and with on-demand opportunities to `deliberately practice' to maintain them, will, as did our young student, Peter Smith, corne to realize that such skills are thé gateway to thé appropriate ordering of tests and images. This will actually diminish thé need for thé unnecessary intrusion of diagnostic technology into thé patient's life. Such imaging technologies, despite their tendency to reveal thé présence of unknown benign lesions and raise patients' fears falsely, still, on balance, advance thé early diagnosis of less benign but curable pathologies. Simulation and virtual-reality technology have thé ability to allow practice and rehearsal of invasive procédures specific to an individual patient's anatomy and pathology, thus saving thé patient unnecessary surgical exploration and diminishing thé risk of insertion, ablation or incision errors.

Finally, one thing is certain. Although there will be advances in thé médical sciences and technology over thé next 20 years "of which we cannot now even conceive", thé innate nature of humankind will not change. Illness, real or imagined, will still engender fear and anxiety and require explanation, reassurance and succor. Earlier and more efficient diagnosis brought about by better diagnostic technologies and better skills training of doctors can free up more of our time for communication, discussion and compassionate care. Ensuring that thé latter occurs is thé real challenge.The technology has proven itself.

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KEYWORDS: *AIDS; change; design; family communication; hemophilia; medical issues; medical simulation; modeling; redesign; sex education; village development.*

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THE HEMOPHILIA PLANNING GAMES and BLOOD MONEY

Title, Designer(s), Year of Creation		
THE HEMOPHILIA PLANNING GAMES; John Gagnon and Cathy Greenblat, 1974-1975	Medical personnel and policy makers working in hemophilia care; National Heart and Lung Institute and the National Hemophilia Foundation	[illegible]
[illegible]	The general public, families of hemophiliacs, policy makers with health interests, physicians and nurses in training or practice; National Heart and Lung Institute and the National Hemophilia Foundation	[illegible]
POMP AND CIRCUMSTANCE; Cathy Greenblat, Linda Rosen, and [illegible]	Adolescents; adults concerned with understanding adolescents' issues and perspectives	An abstract two-person risk-taking exercise modeling the circumstances leading to premarital pregnancy; designed to be played in groups of up to 30 participants for sex education and to sensitize adults to some of the reasons for ineffective use of contraception by sexually active adolescents
CAPJEFOS: The Village Development Game; Cathy Greenblat, Philip Langley, Jacob Ngwa, Ernest Mangesho, Foday MacBailey, and Saul Luyumba; 1985 and 1990	Students or practitioners of development, health, agriculture, rural economics, village management and planning, especially in Africa, but useful in any developing country; UNESCO and the Pan African Institute for Development–West Africa (first version, 1985), World Health Organization (revision, 1990)	A complex simulation of many dimensions of Third World rural development and community life. The revision focuses more fully on dimensions useful for training health practitioners in the Third World.
THE ENCOUNTERS FAMILY OF SIMULATIONS; Cathy Greenblat, Diana Shannon, and John Gagnon, 1988-1991	[illegible] counseling settings[a]	[illegible]

NOTE: UNESCO = United Nations Educational, Scientific, and Cultural Organization.
a. See Table 2 for details.

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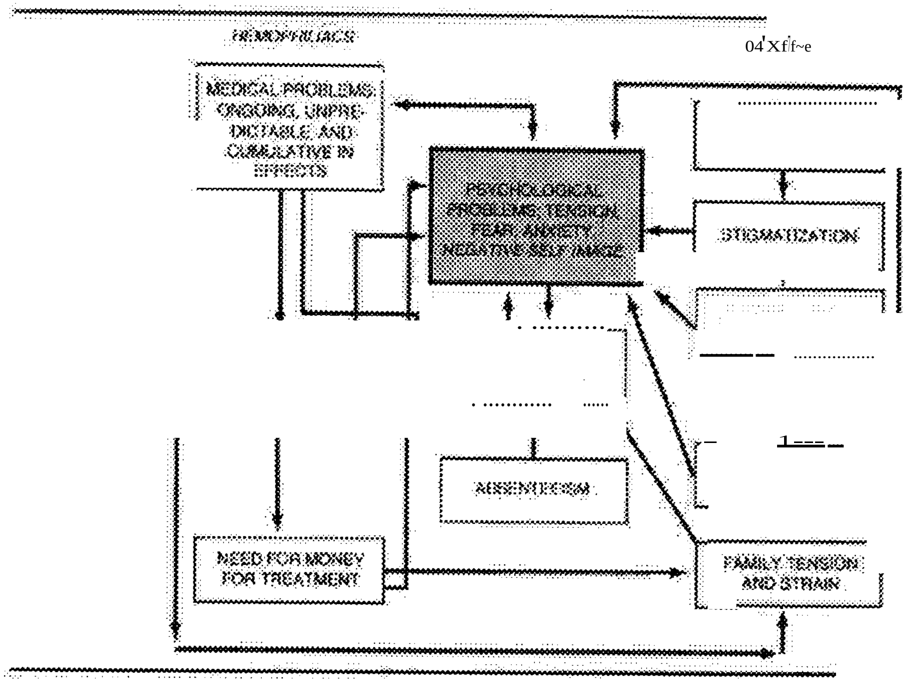

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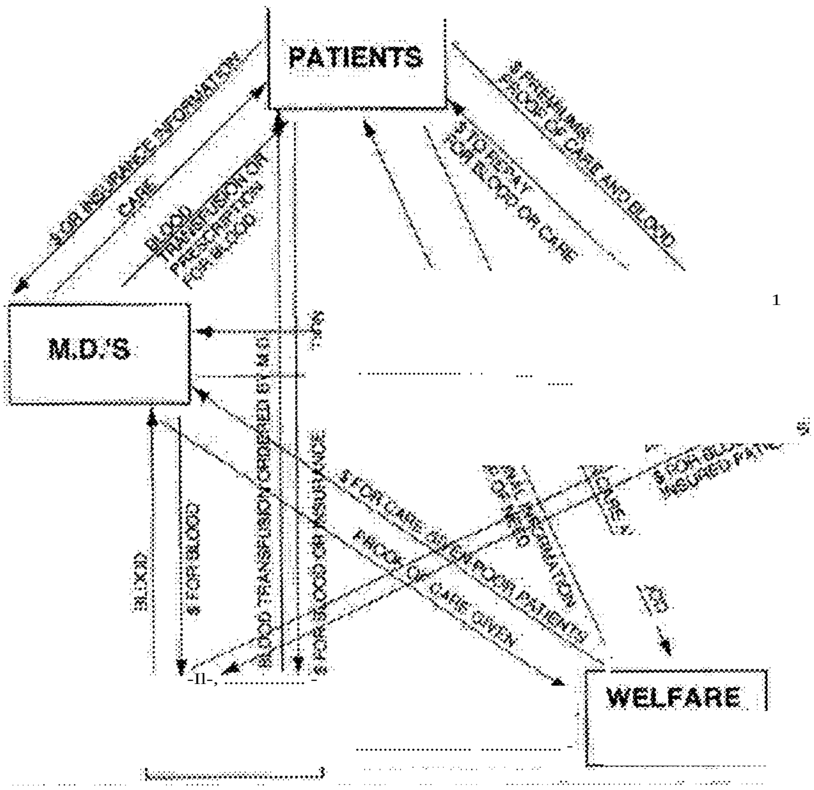

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TABLE 2: The ENCOUNTERS Family of Structured Role Play Simulations

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ENCOUNTERS WITH AIDS: Women, hemophilia, and HIV	Mothers, wives, and sexual partners of men with hemophilia	Canadian Hemophilia Society	Canadian Hemophilia Society
CRITICAL ENCOUNTERS: Health care workers and HIV	Nurses, social workers, doctors in English-speaking industrialized countries	World Health Organization, Global Programme on AIDS	Not distributed
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Guest editorial: Twenty-five years of ABSEL research

Simulation & Gaming,- Thousand Oaks; Mar 2001, Alan L Patz;

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[Headnote]

The authors of the following six articles have been and continue to be leading and significant contributors to ABSEL research and to the organization itself. In fact, most are past presidents, fellows, or both. Their commitments to ABSEL's success have included serving in all or several board of directors positions, acting as chairs and discussants at annual conférences, charting research paths for new members, and taking important positions in the publication of Simulation & Gaming. Many other similar contributors may be noted simply by reviewing ABSEL's Web page.

As a relative newcomerjoining at the beginning of ABSEL's 14th year, I have been privileged to know and work with most of these people and enjoy the benefits of their reviews and comments on my research. Although many could and should be mentioned in this regard, only one is-that is, J. Bernard, "Bernie," Keys who has been a supportive colleague over the years and who suggested this special issue. He was unable to continue as a coeditor, but his influence is clear in all that follows.

An Overview

The included articles vary significantly over ABSEL's landscape, and this is most desirable to grasp the general nature of the research territory. However, there are several continuous paths among them. One will be presented here.

ABSEL's Two Thrusts

The Goosen, Jensen, and Wells article followed by the Graf article form a comprehensive treatment of the learning benefits of simulation and experiential exercises. Goosen et al. warn that in business administration there are often conflicting theories, and a simulation can incorporate only one in a given functional area. Therefore, simulation designers have to choose what to incorporate in their game, and it is very easy for a simulation to reflect the biases of the game designers. Equally if not more important, a prospective user of a simulation must carefully examine a simulation to determine whether a given one reflects what is desired to be taught.

Although the Graf article covers many of the same points in the experiential area, it has an interesting history that will be of importance to many readers. In fact, it is only one of three articles designed to provide a complete AB SEL proceedings background/ literature search of what already has been done in the experiential learning/experiential exercise area. Although Graf covered the decade of the 1970s, Lane Kelley and William D. Bice took the 1980s, and John Butler examined the 1990s. The three articles were presented at the 1999 ABSEL conférence in Philadelphia and appeared in the 1999 proceedings. Thus, in addition to the included coverage of the 1970s, interested readers may review the other two decades by accessing the 1999 proceedings.

What Went on With Simulations?

Continuing this historical approach with simulation algorithms, Gold and Pray take up the question of internal validity in the design and modeling of business simulations. Over the past two decades, the ABSEL conférence has been used as a way for game designers to share the algorithms embodied in their games and get feedback from the academic community.

They conclude that the published research has clearly improved the modeling of business games, that the newer games run more efficiently on microcomputers and behave rationally with results that are consistent with modem theory. Moreover, newer games embody many of the topical issues that businesses confront in the 2 1 st century, including new product development challenges, continuous improvement and quality management issues, and human resource challenges.

In a similar vein, the Fritzsche and Burns article traces the development of marketing simulations coinciding with advances in computer technology. The technology has served as the vehicle for the growth and increasing sophistication of marketing simulations. ABSEL's role in this development has been to serve as a conduit for the development and dissemination of concepts, ideas, and experiences via conférence presentations, discussions, and publications. Many ABSEL-related developments have been incorporated in subsequent editions of existing and new simulations, andABSEL has been the primary academic organization promoting the development and use of marketing simulations.

Then, Faria takes an overall approach to the entire simulation area. More than 100 gaming articles are reviewed covering such research topic areas as the changing nature of business games, correlates of simulation game performance, the effectiveness of business games in strategic management courses, a comparison of business gaming to other teaching methods, and the cognitive and behavioral nature of learning through business simulation games.

The Future

The Patz, Keys, and Cannon article closes this issue with a "Merlin" empirical study of ABSELs future in the year 2005 and how to get from here to there. Several themes emerge.

Among them are that ABSEL is poised for prominence because of the growing importance of pedagogical research. Pedagogical research is aimed at producing results-not at advancing the current fashionable and almost always fleeting notions of an elite at a local university or editorial staff of a widely distributed journal.

Second, with each passing year, ABSEL becomes more international in its membership and outlooks. This will enhance our current inventory of simulation and experiential exercises as well as providing an avenue for AB SEL-CO, a for-profit company.

Last, AB SEL will take a key leadership position in pedagogy by student-centered education models. The products, principles, and research consultation that will make this a reality are covered in the final paragraphs of the article.

[Author note]
-Alan L. Patz Guest Editor