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Microsimulation (PC Simulation) in Emergency Health Care Learning and Assessment

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Learning Objectives: 1) To define microsimulation and macrosimulation and describe their strengths and weaknesses. 2) To describe and discuss the importance of debriefing and the challenges related to microsimulators. 3) To summarize the opportunities and challenges to using microsimulation as an assessment instrument and describe a solution to the problem of training health care personnel with microsimulation.

Abstract

Microsimulators—simulators that run solely on a computer—allow for both practice and assessment of learning objectives at higher cognitive levels than written tests or even oral boards, in some cases. In a microsimulator, the learner is required to actively use knowledge and cognitive skills to investigate and treat computer-simulated cases that will respond appropriately to the treatment. Microsimulation provides a convenient and economical way for the learner to not only practice the approach to more common conditions, but also practice how to deal with some of the rarer conditions. This article describes characteristics, strengths, and weaknesses of microsimulators compared with other simulators. The challenges of, and solutions to, using microsimulators as assessment instruments are described and practical applications are discussed.

Background

Simulation is now widely recognized as an important educational intervention that can reduce the number of human errors and prevent adverse events.[1] The number and types of learning objectives that can realistically be met with simulation has increased significantly with the introduction of microsimulators that allow learners to treat simulated patients on their PCs. Many of the breaches of protocols made during clinical care relate to a lack of knowledge about which algorithms to follow, errors in drug dosages, and faulty clinical reasoning,[2] most of which can be addressed by the use of microsimulators. Microsimulators allow for both practice and assessment of learning objectives at higher cognitive levels than written tests or even oral boards, in some cases. In the simulator, the learner is required to actively use knowledge and cognitive skills to investigate and treat computer-simulated cases that will respond

The author has a commercial affiliation with one of the companies named in this article.

appropriately to the administered treatment. It provides a convenient and economic way for the learner to not only practice the more common conditions, but also practice how to deal with some of the rarer conditions.

Thus far, microsimulators have primarily been adopted by large-scale organizations like the U.S. Army (for the training of medics), the American Heart Association (AHA: Advanced Cardiac Life Support [ACLS]) training), and the Red Cross in a number of countries for first aid training of laypersons. It has been characteristic that the early adopters tended to be larger organizations because the integration of microsimulators typically takes more resources than many other simulation initiatives. To benefit optimally from the use of microsimulators, the curriculum needs to be reviewed carefully because microsimulation typically offers to address thousands of learning objectives in a given topic (but usually not all of them), so frequent use alongside the existing curriculum is an obvious opportunity for many. Alternatively, a new and very condensed curriculum can be custom-developed, as is the latest generation of self-directed learning curriculum from the AHA. In this course, the learner can earn an ACLS card by answering a short written test on facts, as well as passing a skills test, based on treating 10 patients. Courses such as this require that the microsimulators are developed specifically with this purpose in mind to meet the full requirements of the course. The number of advanced simulators and simulation centers has exploded since the early 1990s. At that time there were less than 20 advanced full-scale simulators in use at less than a dozen centers; today there are thousands of simulators and hundreds of centers.

In addition to this, the acceptance of using simulation has widened significantly. Curricula where multiple types of simulators are used (either in skills laboratories or as a part of specific courses) are now common. The scope of the simulators is much broader as well. In the early 1990s, simulators were primarily used for anesthesia training, whereas today the use of the patient simulators encompasses most medical disciplines, including nursing, intensive care medicine, trauma, and specialized military subjects such as CBRNE (chemical, biological, radiation, nuclear, and environmental) disasters/warfare.

The Role of Feedback

There has been a global shift in medicine away from frontal, didactic teaching to knowledge acquisition through problem-based, interactive learning. This approach, first implemented at McMaster University during the late 1960s,[3] has been adopted by several major medical schools, led by Harvard Medical School in Boston and the University of New Mexico.

A major theoretical base for problem-based learning is experiential learning. Experiential learning (although in fact already acknowledged by the ancient Greek philosophers) was initially described early in the 20th century[4] and was further elaborated throughout the century.[5-7] The theory and application of problem-based and experiential learning has led to, and will continue to generate, shifts in the roles of the learner and the teacher.

In this model, the student is an active learner and constructor of knowledge instead of a passive knowledge receptacle. The teacher is a facilitator, guide, and co-learner. The path to higher knowledge and expertise in complex fields is understood as the integrated sum of a large variety of experiences in the context of deliberate practice and rapid feedback cycle. To this end, the trend in medical education is toward more case-based teaching, small group learning exercises, and the earlier integration of clinical contexts into the basic sciences.

Seven insights have been inferred from this body of work[8,9]:

1. Learners are not receptacles of knowledge but rather active and unique creators of their own learning.
2. Learning is about ensuring the understanding of the subject matter by each individual through the establishment and revision of patterns, relationships, and connections.
3. Every student learns with, and perhaps despite, the teachers. Most learning occurs implicitly, arising from interactions with complex situational cues from patients, peers, and mentors.
4. Direct experience decisively shapes individual understanding—the brain's activity is in direct proportion to the student's engagement with actively stimulating environments.
5. Learning occurs best in the context of compelling "presented problems,"when people are confronted with specific, identifiable problems that they want to solve, and that are within their capacity to solve.
6. Beyond simulation of problems, learning requires active reflection—high challenges produce major surges in short-term neural activity (beta level). Building lasting cognitive connections requires further considerable periods of reflective (alpha level) activity. In the absence of reflection, the solving of a problem usually ends the learning encounter at a point well short of the cognitive reorganization required for deep learning.
7. Learning occurs best in cultural contexts that provide enjoyable interaction and substantial personal support. Effective learning is both interactive and social. Key features of the desirable social milieu in new learning situations are direct personal support for manageable risk-taking (with its occasional negative consequences) and frequent opportunities for peer interaction, assessment, and feedback.

Constructivist learning approaches, which have made their way into medical education as they have in industry and the business world, emphasize in situ learning environments. These recognize the power of experiential learning and the importance of context during training for the transfer of skills to actual operations.[10] As opposed to traditional behaviorist learning approaches (controlling the learner's behavior through rewards and punishments), or to a purely cognitive approach (a focus on how individuals learn through processing, remembering, and using information), constructivist theories stress the importance of group learning, of culture, and of the impact of real contexts on individuals acting in a group. The benefits of constructivist learning curricula may include more sustained use of knowledge and skills, improved application of that knowledge in context (greater activation of knowledge), and "double-loop learning" in which trainees challenge hidden assumptions and try to improve existing practices.[11] The use of simulators supports constructivist-learner–focused approaches that would be unethical, inefficient, and unfeasible if used in on-the-job apprenticeship-style training.

Currently Available Simulators and Their Strengths and Weaknesses

Simulation is the concept of building an environment or part of an environment resembling a real-life environment in appearance and behavior. There are two kinds of simulators for health care education: macrosimulators and microsimulators. Macrosimulators have a physical component, usually a mannequin or a body-part module, and microsimulators are purely computer-based. Both types can be further regarded as either simple or complex, depending on the complexity of the topic to be learned. Although the micro/macro differentiation is discrete, the simplicity/complexity aspect is not. Simple simulators, often called part-task simulators, teach simple algorithms or procedures, involving only a few aspects of a problem. Complex simulators target more complex issues that integrate several aspects of a problem. These four types of simulators have characteristic advantages and disadvantages (Table 1). It is important to note that the technical complexity of the simulator is independent of the complexity of the topic to be learned. There are several technically complex but educationally simple macrosimulators and microsimulators.[12]

Microsimulators are an important adjunct to macrosimulators. They play an important role in medical education, for both laypersons and health care professionals. The remainder of this discussion will focus on their contribution to this learning experience.

Microsimulators

Microsimulators provide autonomous, cognitive training. They differ fundamentally from macrosimulators in that they do not have an operator to run the simulations and provide educational feedback. This is not important for most of the simple microsimulators, which, for instance, allow the user to experiment with the pharmacokinetics and pharmacodynamics of drugs (KinView Opioids [Sophus Medical ApS] Copenhagen, Denmark) or GasMan (Med Man Simulations, Inc., Chestnut Hill, MA, USA). It is, however, of vital importance that complex microsimulators are able to run the scenarios and debrief the trainee autonomously.

Microsimulators have the clear advantage over macrosimulators of accessibility because an increasing number of people have access to a PC either at work or at home. The programs are relatively inexpensive (US $80-280 for single-user licenses) and can be used informally. Microsimulators cannot address issues at the same complexity level as macrosimulators. They can be used for training at high cognitive levels but not for crew (or crisis) resource management, leadership, or communication. Microsimulators are close to ideal as learning tools to learn and practice cognitive problem-solving strategies in many different clinical circumstances. This allows the more expensive, full-scale macrosimulator training to be focused on developing and extending the more complex issues that require physical equipment as well as personnel.

Microsimulators provide an opportunity for the systematic learning and practice of a wide range of cognitive issues. They are easier to access and provide systematic feedback opportunities (high quantity and focus of training), and therefore may be able to train the user at a higher level of cognitive complexity than would be achieved

Table 1. Strengths and Weakness of the Four Main Types of Simulators for Medical Education

	SIMPLE	COMPLEX
MACRO	**Strengths:** - Opportunity for hands-on training of specific manual procedures (IV insertion, chest compression/ventilation, etc.) - Often relatively inexpensive (apart from some of the very high-tech simulators) - Can be used for training and testing without risk to patients **Weaknesses/limitations:** - Not easily accessible - Often instructor based with logistical problems (co-ordination needed)	**Strengths:** - Opportunity for high-fidelity training/certification of team cooperation, communication, leadership (crew resource management), i.e., interpersonal issues can be taught - Can be used for training and testing without risk to the patients **Weaknesses/limitations:** - Relatively expensive to acquire and run - Not easily accessible (usually the simulation has to take place in a dedicated area) - Some are not mobile - Primarily available in a limited number of areas (anesthesiology, cardiology and intensive care) - Instructors and particularly debriefers must be educated in several topics including teaching, psychology, and the specific medical issues related to the simulation
MICRO	**Strengths:** - Opportunity for dynamic explanation of theoretically difficult issues, e.g., pharmacology, physiology - Opportunity to train part of the relevant treatment or diagnosis, e.g., ECG diagnosis - Relatively inexpensive - Easily accessible - Can be used for training and testing without risk to patients. Expertise from several resources can be systematically assembled step by step **Weaknesses/limitations:** - Limited application in certain areas (only a limited number of topics are optimally learned this way)	**Strengths:** - Opportunity for exposure to large number of cases - Relatively inexpensive - Easily accessible (can be used wherever there is PC access) - Cost-effective testing/certification - Expertise from several resources can be systematically assembled step by step **Weaknesses/limitations:** - Limitations in the modalities that can be simulated on a PC - User interface may constitute a barrier to learning - High demands for good autonomous debriefings

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Figure 1. The user interface of the microsimulator used by the U.S. Army 91W Medics training program. (Laerdal Sophus A/S, 2003, Copenhagen, Denmark)

with macrosimulator training. Microsimulation also opens possibilities for simulation of scenarios in which the decision-making is context-specific. When laypersons apply basic life-survival skills, the nature of the location plays an important role in the decision-making process. This contrasts with full-scale simulation or role-playing in which the surroundings have to be imagined.

However, it must be emphasized that, whereas microsimulation can confidently be used to develop knowledge and problem-solving strategies, it deals less well with human factors. In particular, the stress of real-life crisis events (or crises) cannot be reproduced in microsimulations. The ideal complex microsimulator provides credible simulations with intelligent, context-specific evaluation of the trainee's performance.

Further advantages of miscrosimulators include:

- Help is always available at any stage (the help can also be in context—the software "sees" where the problem is and displays the appropriate help menu).
- A pause mode is typically available so that the trainee can look at the help menu, read up on some information, or even have a break. The large-scale physical simulators do not readily lend themselves to such pause modes.
- The program can provide an exact and times list of all interactions of the user with the program. This list can be used for debriefing and feedback purposes. (Full-scale simulators do not typically detect all interactions such as a change in fresh gas flow rates to a bag-mask ventilation system.)
- The microsimulators lend themselves to an introductory session in a large group. This is particularly effective in a computer laboratory in which all users have their own computer.

Complex microsimulators are often confused with multimedia applications, which are primarily based on one-way communication of knowledge from the PC to the user. The two approaches differ fundamentally in the extent to which the user is involved in solving the problem. Simulation is closer to "practice by doing." Well-made simulators give the user a feeling of actively solving the problem. For instance, the users see the dynamic changes of their interventions; these changes are also proportional to the magnitude of their therapy. On the other hand, many multimedia programs merely tend to stimulate passive acquisition of knowledge, similar to video teaching and reading. The multimedia programs are also called "page turners" with no modeling and always presenting the same "page" irrespective of the fine gradations of therapy.

Complex microsimulators with intelligent and focused feedback are rare and the penetration and use of microsimulation is presently rather limited.

Applied Microsimulation

Although the idea of algorithm training on computers is not new, few microsimulators are available for training in anesthesia, intensive care, or emergency medicine for the education of professionals and in first aid training for laypersons. A few early microsimulators for anesthesia simulation were made during the late 1980s and 1990s, but the concept of combining advanced PC simulation with elaborate feedback technology was not introduced until the ResusSim 98 project.[13] This was endorsed by several international authorities, including the European Resuscitation Council, the Australian Resuscitation Council, and the Resuscitation Council of Southern Africa. From the late 1990s, microsimulation has been used increasingly for training of both prehospital and in-hospital staff in acute care medicine, although the focus has been on Advanced Life Support, ACLS, and more medical patients such as those with asthma, intoxications, and the like. In early 2003, the U.S. Army instituted their large-scale 91W Medics training program that, apart from the ACLS components, also included a sizable module with 25 CBRNE (chemical, biological, radiation, nuclear and environmental) situations (Figure 1).

Until 2003, when the AHA launched their new self-directed learning ACLS program, “HeartCode ACLS Anywhere,” microsimulation had only been used as an adjunct to existing training. However, HeartCode ACLS (which is based predominantly on microsimulation) allows learners to renew their AHA ACLS provider card as long as they also pass a short skills test. This was a first example of the use of microsimulation as an assessment instrument.

Microsimulation has also been used in the education of laypersons. The national Red Cross Societies in a number of European countries have used microsimulation as an adjunct for first aid education since 2000.

Feedback and Debriefing in Medical Simulation

Microsimulation and macrosimulation differ significantly when it comes to debriefing—the heart of all simulation. In complex full-scale macrosimulation, the participants are typically debriefed by the instructor who has been guiding the scenario, using video recordings of the sessions or by re-playing the scenario. The major challenge lies in enabling instructors to use a wide range of skills in interpersonal and pedagogical, as well as medical, areas. In microsimulation, the major challenge is the demand for reliable, autonomous performance by the software.

In simple microsimulation, standardized feedback is generated by subtracting the actual performance from a given set of recommendations, producing a banal “error signal.” Focused feedback should optimally evaluate the learner and provide feedback on the actual performance. It should be based on the assumption that he or she tried to perform optimally, but needs some help in improving performance. Obviously, one of the main advantages of this approach is that the combination of relevant simulation and feedback can both focus on the teaching points and target the trainee.

0 **Debriefing**
1 Brad Stephens
3 Diagnosis: VT Arrest
6 0:03 ✓ You shook the patient's shoulder. The patient was unresponsive. It is correct to assess responsiveness here.
7 × You should have considered opening the airway at this point.
8 0:05 ✓ You examined the chest. There are no breath sounds. The chest is not moving up and down. His skin is cold and blue. It is correct to check for breathing.
10 0:13 ! You performed a head tilt-chin lift. Consider opening the airway before checking the breathing.
11 0:16 ✓ You gave the patient 2 breaths. It is correct to give 2 breaths at this point.
12 0:28 ✓ You checked the pulse. There is no pulse. It is correct to assess signs of circulation.
16 0:37 ✓ You attached the shock electrodes for the defibrillator. It's correct to prepare for defibrillation here.
18 0:46 ✓ You administered an unsynchronized biphasic shock of 20 J. You should consider using a higher energy level for the shock. The current guidelines recommend up to 200 J for biphasic shocks.
19 0:54 ! You administered an unsynchronized biphasic shock of 150 J. You did it! The patient was successfully defibrillated. Always remember to say 'Stand clear' before you administer a shock.
21 1:02 ✓ You performed a head tilt-chin lift. This is the correct action here.
22 1:03 ✓ You examined the chest. There are no breath sounds. The chest is not moving up and down. His skin is quite cold.
23 × You forgot to check for a pulse at this point.
25 1:07 ✓ You started ventilating the patient.
27 1:23 ✓ You obtained IV access in the neck.
30 1:38 ✓ You placed an endotracheal tube. It is correct to try to secure the airway.
31 1:41 ✓ You resumed ventilating the patient.
32 1:54 ✓ You listened to the patient's lungs. The breath sounds are normal. There is no indication of a misplaced tube.. The percussion note is normal over all areas.
33 × It is extremely important that you accurately confirm the placement of the endotracheal tube. This can be done with an EDD or by capnography.
34 × You should secure the tube either with tape or a commercial tube holder to avoid displacement.
35 2:03 × The ventilation rate was 22. The correct ventilatory rate for a non-breathing patient is app. 10-15 breaths / minute, continued hyperventilation or hypoventilation may be deleterious to the patient.
40 2:17 ✓ You attached the pulse oximeter.
41 ! Consider attaching a 3-lead ECG monitor here as it might provide you with further useful information about the electrical activity of the patient's heart.
42 2:24 × The oxygen rate was 9.0 L/min. You should use at least 10 L/min of oxygen for this system.
44 3:32 ✓ You transferred the patient to ICU. It was reasonable to transfer the patient at this point.
45
46 **Here are some general comments about the scenario:**
47 You were successful in obtaining return of spontaneous circulation (ROSC) in this patient. Applying the correct ACLS protocols is vitally important in a time-critical event like a cardiac arrest.
49 Outcome:
50 You got 64%.
51
Profile: Clinical Pharmacologist
52 Read more about the management of this case in the ACLS Provider Manual: VF/Pulseless VT
53 Disclaimer:
54 Emergency cardiovascular care is a dynamic science and advances in treatment and drug therapies occur rapidly. Prior to prescribing or administering, practitioners should carefully review all prescribing information associated with each agent discussed in this offering with respect to recommended dose, indications and contraindications.

Figure 2. An example of a computer-generated debriefing (from AHA’s HeartCode ACLS Anywhere). (Laerdal Sophus A/S & American Heart Association, 2004, Dallas, TX, USA)

The technical difficulties in autonomously evaluating individual performance are significant. The user often addresses more than one issue concurrently. For example, advanced airway management may be performed at the same time as following a specific algorithm for a cardiac condition. This presents problems in evaluation because the user does not clearly mark which action belongs to which strategy. In addition, several actions may be relevant, but not crucial, to solving the problem; this further complicates the debriefing. Optimal debriefing technology must be able to distinguish between important and less important actions and mistakes.

In the MicroSim programs (AHA's HeartCode is based on MicroSim), a unique debriefing technology, AID (Automated Intelligent Debriefing), has been used. Based on modern research in pattern recognition and educational theory, AID has become an umbrella name of a range of technologies aimed at intelligent debriefing. It is capable, for instance, of detecting different algorithms mixed in a sequence of actions and can prioritize actions and mistakes. AID can provide feedback on parts of the treatment (e.g., the cardiac treatment algorithm) without being "disturbed" by other actions performed in tandem. A sample debriefing is depicted in Figure 2. The feedback can be presented either in different visual formats or in a text format. The limited present use of microsimulators may be the result of the lack of relevant feedback technology. However, with technologies such as AID, this may change as new and more advanced microsimulators emerge.

Challenges When Using Microsimulators as Assessment Tools

When the AHA moved to simulation-based self-directed curricula for the 2003 release of HeartCode ACLS Anywhere, a number of challenges had to be overcome. Early tests carried out during the development showed that only a small fraction of the users responded to the debriefing and assessment by refusing to accept that a computer can evaluate their performance in a fair and consistent manner. The excuses were many and they ranged from the simulator interface being difficult to use, the time it took to familiarize oneself with the debriefing, to the assessment being wrong (even in places where the debriefing was inarguably correct). This phenomenon became a major obstacle in the development because other domains have hypothesized that some people may perform worse after simulators than before because of a rejection of the learning environment and thus a confirmation of their sometimes-inadequate behavior. The problem was complicated because, in some cases, learners actually needed more time to get acquainted with the user interface before attempting to pass the test but were frequently "sucked" into the simulation and thus directly into the actual test cases for evaluation. The challenge was finally dealt with by introducing a simple educational technique that turned the responsibility for the quality check over from the computer to the individual (Figure 3).

Consciously Incompetent. After treating a simulated case on the screen, and prior to receiving the computer debriefing, the learner is asked to evaluate whether the performance in the simulator was acceptable. This way the learner can discard attempts that were influenced by whatever made the treatment suboptimal, and at the same time the learner is stimulated to be conscious about the quality of what actually occurred during the scenario. An attempt can be discarded as many times as the learner wants, as it is considered safe to be *consciously incompetent* (as long the learner is going back to practice more).

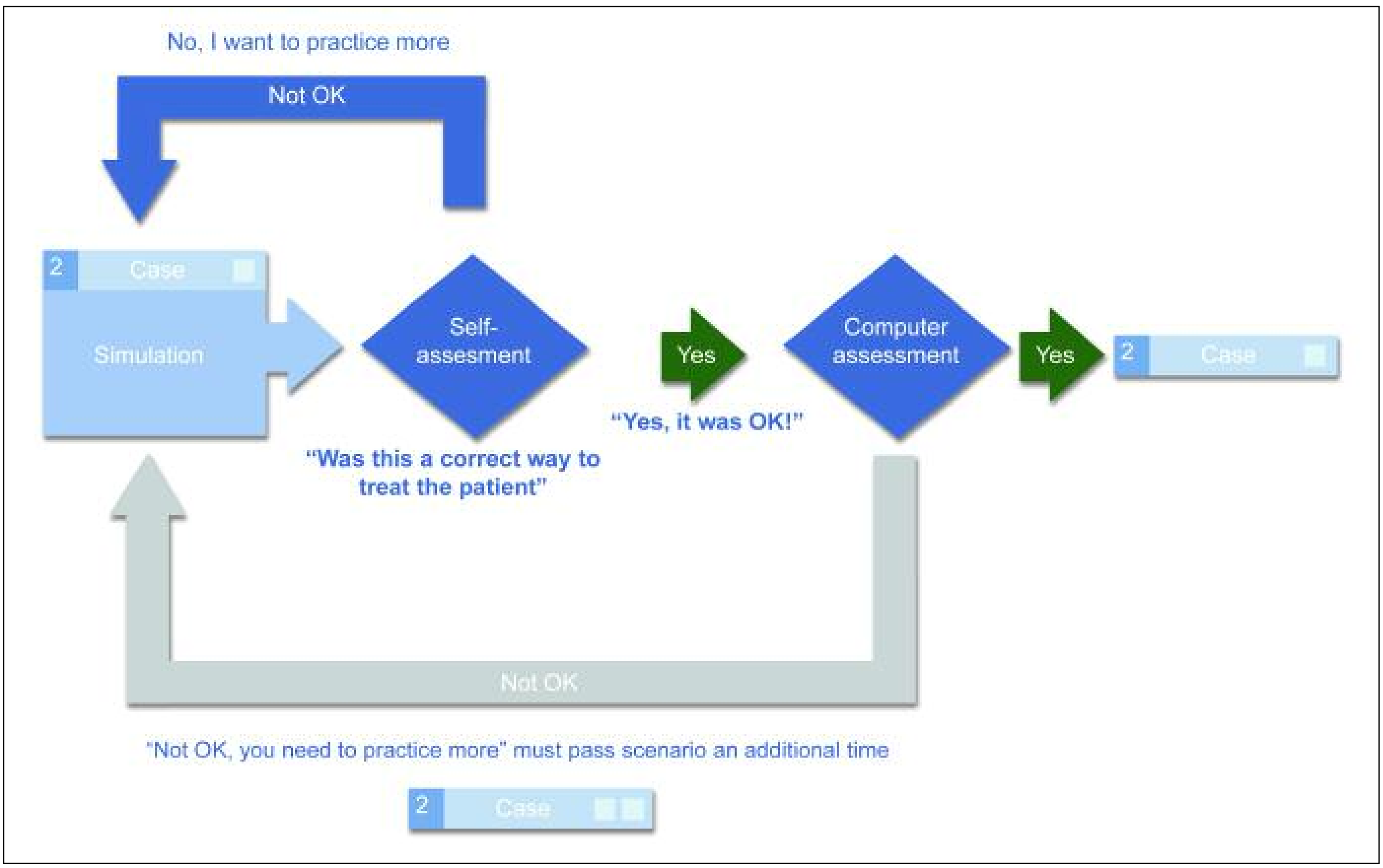

Figure 3. The concept of self-assessment.

Unconsciously Incompetent. If the learner believes that the performance was acceptable, the attempt is submitted and the computer compares this with the automatically generated debriefing. If the computer agrees that the learner is considered consciously competent in treating this case, then the case is considered “passed.” If the computer disagrees, then either the computer is wrong or the learner is *unconsciously incompetent*. If the learner still often considers that the computer is wrong even when this is not the case, then this could be a major barrier to learner acceptance of the technology. In this case, the learner can appeal the “verdict” to a human evaluator. Final tests indicated this might not, after all, be a major issue, and in practice (with tens of thousands of people now having gone through this curriculum) this is a rare exception that occurs in less than 1/1,000 participants (each treating 10 cases).

Consciously Competent. In the case of the unconsciously incompetent learner, the learner is required to demonstrate *conscious competence* (treat appropriately and know that the treatment was appropriate) in up to three subsequent attempts (depending on how many times the learner has demonstrated unconscious incompetence). This very strong focus on making the learner conscious about the quality of the treatment and the subsequent consequences in terms of having to spend more time on a given topic makes the compliance data even more convincing. In other words, this approach has apparently effectively solved the compliance problem with using microsimulators for assessment purposes (although it obviously requires a very high intrinsic quality of the assessment and debriefing instrument).

Unconsciously Competent. The final category—the *unconsciously competent* learner—did not appear to be a substantial issue when training health care professionals (although more investigation can be done in this field). Another difficulty showed itself, however, when the self-assessment method was applied to layperson education in basic life support. In this case, tests carried out during development showed a large percentage of the learners dismissing attempts that were acceptable (even attempts with only marginal errors were now frequently dismissed). While interviewing the test subjects, it became clear that this was from a variety of reasons. Many of the test subjects had no intuitive “barometer” for what was sufficient, particularly because many of the patients did not become conscious even after successful treatment (e.g., defibrillation). Secondly, many learners were so conscious about the specific rules to be followed that they could identify mistakes in their protocols, but could not differentiate between small and large mistakes, and thus dismissed all attempts with any kind of deviation from the protocols. Finally, many of the learners stated that they dismissed attempts because they still did not feel ready to do this in real life (it should be noted that this testing was done prior to practical cardiopulmonary resuscitation training).

All of these challenges were dealt with by adjusting the feedback the learner receives after the first case that is unnecessarily dismissed. The primary change was to be much more supportive in the feedback provided and to explicitly explain some of these aspects. However, this indicates that use of microsimulators for education of laypersons poses some challenges that are substantially different from those from health care personnel (at least in terms of volume and frequency), but also indicates that a similar problem (spending too much time with the simulator) may occur when introducing microsimulation as assessment instruments at entry-level training (because these groups are likely to share at least some of the characteristics of laypersons). Even so, this final challenge to be overcome is solely related to training efficacy rather than to the quality of the assessment/training or, for example, compliance (at least not directly), and the major challenge to date for the use of microsimulators for assessment appears to be overcome.

Face Validity and Simulation

Face validity is a concept central to simulation because it has been shown, in both military and aviation simulators, that objective realism is not the most important determinant of the impact of simulation. It is more important that the simulation “feels” right. What matters is each individual’s perceived reality of the simulated situation. Therefore, it is absolutely crucial that a given simulation concept is based on clear and focused learning objectives, and that the simulators (i.e., the tools) are chosen thereafter, according to the needs of the individual. Because the literature on evidence-based medical education by simulator is scarce, the main source of evidence of effectiveness is to be found in areas such as aviation and military simulation.

Conclusion

Education of health care professionals is dramatically changing, with a strong emphasis on experiential adult-centered learning. The use of simulations in medicine is a relatively recent phenomenon. However, there are many more opportunities across various medical fields to expand the use of simulations. Simulation addresses many of the present deficiencies in clinical education in these domains.

Four types of educational simulators are available for health care education. They are simple (part task) and complex microsimulators, and simple and complex macrosimulators (full-scale simulators). There has been a tendency to see full-scale simulators as the ideal solution for all educational simulator training. However, each of the these groups has different strengths and weaknesses in achieving educational goals. Microsimulators are a complementary tool to full-scale and other macrosimulators. Their role in medical education will become increasingly important because it is now possible to make intelligent, autonomous microsimulators. Using a combination of microsimulators and macrosimulators will allow a wide range of cognitive and behavioral skills to be taught. The development of microsimulators—as soon as the realism is sufficient—should focus on the intelligent, educational feedback in the debriefing. This challenge for microsimulators may become their greatest asset in medical education.

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