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Challenges of biological realism and validation in simulation-based medical education

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Summary

Overview: Simulation, both physical and computer-based, has a rich history in support of medical education. Essentially all these efforts have been aimed at instilling concrete measurable skills, akin to vocational training. They present learners with choices, facilitating a degree of learning by doing. The sets of learner choices are usually limited, with choices clearly classified into "right" and "wrong". But much of medicine is not much like a multiple-choice test. The realm of choices is broad and not always easily converted to a short list. The "correct" answer is not always known by the experienced physician beforehand, sometimes not even after the die is cast and the future unfolds. Computer simulation of human disease and its treatment can in principle be tremendously useful in the education of both basic and clinical scientists. This paper describes some challenges in the construction of simulation-based "liberal arts" biomedical education.
Objectives: The educator attempting to develop a learning environment based on simulation of biology faces some special challenges. The challenges addressed in this paper are: face validity and deep validity; finding the right degree of realism; authoring biomedical models efficiently; managing randomness. To illustrate the issues, we trace the history of the Oncology Thinking Cap throughout several versions and expansions of educational objectives, and describe the detection and remediation of shortcomings related to these issues.
Design: Dealing effectively with issues of validity and realism can be accomplished if the acquisition of information driving and justifying the model development choices is documented, preferably automatically, during the process. Efficiency in authoring is greatly enhanced by judicious modularity to encourage re-use, and by the use of templated statements rather than raw code or exotic graphical components to represent the instructions driving the model. Randomness can be used to familiarize

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learners with the true relative proportions of types of cases, or to enrich the encountered cases with rarer but more instructive cases. When a learner repeats an encounter with a scenario while changing a single option, proper management of randomness is essential to avoid artifacts of random number generators. Otherwise an outcome change caused by a shift in random number streams may masquerade as an outcome change due to the changed option.
Conclusion: Effective use of computer simulation of human disease and its treatment for biomedical education faces daunting obstacles, but these problems can be solved.

1. Introduction

Simulation as a method to enhance medical education has been the subject of numerous recent reviews [1—6]. A frequent use of simulation is to meet the challenge of providing clinical trainees with sufficient clinical experience, which is becoming more difficult in light of pressures to decrease contact hours of students with patients [7,8] as well as the growing complexity of the health care enterprise. Simulation of patients by computer algorithms [9] and hybrids between computers and devices [10] have been proposed as a solution.

A second potential application is to train students in the art of clinical investigation. This application has received much less attention. As with patient care, the ability to increase practice time in the simulation is an obvious advantage of simulation. Although clinical trial simulations are widely used by statisticians to assist in study design [11—13], their use in medical education has been limited.

A third potential use of simulation is at the biological level. The remarkable explosion of knowledge about the molecular basis of diseases also presents challenges for medical education and opportunities for computer simulation to address those challenges. Acquiring, organizing, and reasoning with this knowledge can be overwhelming to students. In addition, some interesting and creative resources have been developed to teach scientific reasoning with the help of simulations [14—16].

These three kinds of computer simulation applications have similar requirements for building and validating the models behind the simulations, so they can, in principle, be developed with a single unified approach. This is a central mission of the Oncology Thinking Cap (OncoTCap).

In this paper, we focus on just a few challenges of interest relative to contributions of computer simulation to future medical education. To illustrate these challenges, this article traces the evolution of a cancer simulation system with a variety of educational uses, through several radically different versions. Each version has had successes and hard lessons to be learned.

2. Background

Some early uses of computer simulation in medical education were based on decision trees [17,18]. Students were presented with scenarios and a small number of choices. To ensure that the program was performing as it should, pathways through the tree could be checked exhaustively for face validity. The multiple-choice simulator is relevant to helping students learn to reproduce the output of an idealized guideline decision tree, and may be especially helpful in the effort to reduce medical errors [19].

Medical education simulators with physical objects such as mannequins present a much greater set of choices for learners, namely all the physical actions that could be taken by a learner. These need not be exhaustively catalogued, because the reasonable actions are limited and the essential variables describing the choices or actions are continuous and small in number. For many simulators, the response of the system is mostly deterministic. There may be the occasional rare event for a special challenge, or simulated lab values may be varied. However, one rarely sees stochastic elements driven by a model of the biological processes occurring within the patient's disease process and response to treatment. Exceptions are arenas where there is a well-validated physiological model based on physical or pharmacologic rather than biological principles, for example CircSim [17,20].

Connecting a wide set of choices for learners with a biological simulation can in principle create a richer, livelier learning environment. Friedman [4] demonstrated a prototype of a cancer patient simulator based on OncoTCap 2 [21]. The learner, having made a treatment decision in a fairly open choice set, observes the consequences as the model evolves in response to treatment. Then the learner can respond to these consequences with new treatment decisions, leading to further patient evolution by the simulation, continuing iteratively.

Designing a right-sized set of choices for students studying a simulated case is a tremendous challenge. Friedman et al. [22] examined the task of