ABSTRACT

Game-based medical simulations differ from other training modalities in that life processes must be simulated as part of the experience. Biological fidelity is the degree to which character anatomical appearance and physiology behavior are represented within a game or simulation. Methods to achieve physiological fidelity include computational physiology engines, complex state machines, simple state machines and kinetic models. Traditional games also employ health scores that can also be employed for medical gaming. The selection of technique to is dependent upon the goals of the simulation, the types of input expected of the user, the amount of development work possible and the level of fidelity required. Apparent biological fidelity, responsiveness to user inputs and the ability to correct mistakes is often more important than actual biological fidelity.

Keywords: Biological Fidelity, Health Scores, Medical Education, Medical Simulation, Physiology, Physiology Engine, Serious Games

INTRODUCTION

Videogames have been in the life or death business since their inception. Players ‘die’ or suffer injuries in games as a routine matter. Some of these approaches are very simple, such as when Mario is hit by Donkey Kong’s barrel (Donkey Kong, Nintendo Corp.). Others are a bit more sophisticated, such as the progressively bloodied character depictions in Wolfenstein 3D and Doom (id Software). The medical education folks are constantly creating new simulation experiences with ever higher fidelity. The question is, can we adapt approaches from entertainment games to medical simulations or even better, create compelling and realistic medical games? Are there parts that are medically unique? If so, how do we simulate this with an interactive experience? When it comes the biological parts, how much fidelity is optimal? This paper explores the question of simulating the biological processes that make something appear lifelike and medically convincing. The intent is to contrast approaches based upon type of training, development effort and impact on the learner.

PHYSIOLOGICAL FIDELITY

Many training scenarios involve demonstrations of physiological action with an expectation that the learner diagnose a condition based upon the demonstrated physiology, make interventions...
and receive a realistic physiological response as would be seen in a patient encounter. A variety of mechanisms exist that can do with tradeoffs in the fidelity, dynamism and effort involved in their creation.

**Complex Fidelity: Physiology Engines**

A sophisticated and scientifically valid experience with complex fidelity can be achieved through physiology engines. Physiology engines are computer coded mathematical models that simulate body systems. Basic physiology engines replicate the cardiovascular system and the effects of hemorrhage, fluids and medications on the model. Some manikins include such engines. (1) More complex physiology engines are multi-system with large pharmacology libraries and multi-drug interactions. An example of a multi-system model is PhACTS, created by the Applied Research Associates and funded by the Defense Department. PhACTS can readily simulate a wide variety of conditions such as hemorrhage, heart failure, ketoacidosis or hyperaldosteronism. The results of PhACTS outputs are in the form of graphs or data that will closely match results from physiology research studies and textbooks. Although early in its development, PhACTS is open-source physiology and includes common drugs and game engine plug-ins. With such an engine, it might be possible to have a combat game with hundreds of non-player characters, each running their own physiology engine instance so they will have accurate responses to injuries the player inflicts or attempts to treat.

Physiology models are a high end solution that can run in real or accelerated time. They have the capability to mimic realistic physiological activity and can gracefully manage unexpected user inputs. They can cope with the effects of multiple interventions even if those interventions are antagonistic to each other. One problem is that realistic changes in physiology may be too gradual or subtle for the learner to notice unless on-screen indicators readily depict historical trends. Some physiology processes, such as sepsis or chemistry changes, unfold too slowly to be observed during an educational scenario. In these cases, the simulation will appear insufficiently responsive and fail to engage the learner. Ironically, realistic responses to user inputs can reduce the user’s impression of biological fidelity if they are too gradual. The need to closely observe monitor displays while tracking ongoing changes to physiology can and does distract the learner from observing the patient. (2) It is often difficult for a simulation to correlate virtual patient verbal behavior or appearance with the state of the physiology engine. Efforts to demonstrate changes in patient appearance in Virtual Reality (VR) simulations based upon physiological parameters have been attempted and are maturing (3) (see Figure 1).

Physiology engines are often present in high-end medical simulations. Higher end manikins such as the METI (CAE Healthcare) iStan and SimMan 3G (Laerdal) employ physiology models that focus on the respiratory and cardiovascular systems. With these systems, changes in pulse, blood pressure and respiratory rate are concretely accessible from the physical exam of the manikin as well as on a monitoring display. These engines will respond appropriately to artificial ventilation, chest compressions and cardiac medications, for example. The high interactivity and close linkage of the physiological response closely replicates an actual critical care encounter. A shortcoming of manikins is the limited behavioral repertoire and the presence of monitoring displays which are often watched over by learners who neglect the physical exam. They are also mostly static collections of plastic and are not always convincing interaction partners. Manikin features rated by medical students to be most useful include chest rise, palpable pulses, interactive voice and the vital signs display. (2)

Anesthesia simulation is a common application for physiology engines. These can be conducted with manikins, on a computer screen using virtual patient avatars (4) or with a simulated patient monitor (see Figure 2). The most sophisticated manikins can simulate gas
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