Task Specific Simulations for Medical Training: Fidelity Requirements Compared with Levels of Care

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ABSTRACT

There are many virtual and constructive training systems that simulate injuries as well as degrading and improving patient conditions. Most of these systems use simplistic models to mimic the physiological response to the injuries and the response to treatment. For example, when modeling bleeding from a gunshot wound, many of the models are simply based on the amount of blood loss over time. An arbitrary time limit is often established to indicate a failure to save the patient. Little to no consideration is given to the munitions type or to the baseline physiology of the individual who is shot. Also, most of these games and simulations independently reinvent the math models and the physical models of these wounds. Proprietary nature of these diverse simulation platforms results in very little reuse.

This effort will explore how physiology is being represented in several simulation platforms. Targeted virtual and constructive systems include: Pulse, STTC’s Tactical Combat Casualty Care (TC3) game, STTC’s/Forterra’s OLIVE environment, and PEOSTRI’s One Semi-Automated Force (OneSAF). Targeted mannequins include METI’s Human Patient Simulators, Laerdals SimMan and Gaumards simulators. An analysis will be done on the level of fidelity currently included in each of these systems and on the pros and cons of how the physiological and the pharmacological responses are simulated. The analysis will also include a discussion on simulating versus replicating human physiology.

An initial hypothesis is that the higher fidelity medical simulations have interdependencies in the mathematical models representing different physiological sub-systems, such as bleeding, heart rate, blood pressure, etc. An attempt will be made to define a strategy for selecting the correct fidelity of human physiology models as well as ways to reuse existing models.

ABOUT THE AUTHORS

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BACKGROUND

Medicine is advancing at a dramatic rate. New discoveries and techniques are demanding a more rapid and advanced medical education. However, medical education and training has changed very little in more than one hundred years. In the 1880's, Dr. William Halstead influenced American medicine to follow the training he received in Europe. At the time, American surgeons were essentially self-taught, while their German counterparts had direct instruction (Physiological Response to Infection, Trauma and Surgery, 2004). Mentored instruction like this evolved into the "…see one, do one, teach one…" model that has become the standard for today's medical education (Carroll, 2008, p. 49). Unfortunately, this apprenticeship model creates the situation where an inexperienced doctor learns new procedures (with supervision) on live patients. The result is usually positive, however, "...errors that otherwise would not occur are made as residents learn their skills" (Langhan, 2008, p. 467). In 2000, an article in the Journal of the American Medical Association reported that medical errors were the third leading cause of death in the United States (Starfield, 2000). Statistics like these indicate that the medical training model should be updated with the goal of improving patient safety.

The use of human cadavers has been a standard in medical education for decades. Medical students and residents utilize these cadavers for learning anatomy and performing procedures (Langhan, 2008). However, the cost of cadavers is increasing and the availability is decreasing. Compounding the problem is the Global War on Terror which has pushed limits on treatments to a point that soldiers and medics are performing techniques that used to be reserved for surgeons. Increasing the skill levels of the basic medic has certainly saved lives, but it has also introduced over 40,000 new students that require more advanced training. This huge spike in demand along with the growing scarcity of practice assets has forced the military to significantly increase the use of live animals for trauma and surgical training. While increasing live tissue training may be justifiable in the current conflict; the justification will fade as time passes. To address this controversy, the military has mandated that the use of live tissue in training is to be greatly curtailed. The Department of Defense has formed the Use of Live Animals in Medical Education and Training Committee for the sole purpose of finding ways to reduce or eliminate the need to train on goats and pigs.

Medical simulation has emerged as a leading technology to address the problems mentioned above. Simulation offers the ability to practice procedures, receive feedback, document results and repeat procedures, without negative repercussion to life or limb. In response to the benefits of medical simulation, the military and industry have developed a wide variety of simulations for medical training. The range and depth of these simulators cover a large domain, from very simple task trainers to complex full body simulators. All of these simulators rely on some type of representation of human physiology. Some simulators use simple computer-based algorithms to take an emergency medical services student through basic life saving techniques. Other simulators are much more complex, and include full mannequin human patient simulators with integrated, self compensating heart rate, respiration, pulse, oxygen levels, and bleeding (Carroll & Messenger, 2008; Rosen, 2008; McLaughlin, Fitch, Goyal, Hayden, Kauh, Laack, et al. 2008).

THE PROBLEM

Training medical personnel is a very large problem space that includes a wide range of cognitive levels and skill levels. Trainees include emergency medical services, nurses, physician assistants, and doctors. The training that these groups need varies from basic first aid through advanced techniques for saving lives. The next logical question is how advanced does the simulator need to be to adequately train a particular individual or team? Some of the fully functional human patient simulators can easily cost $100,000 or more. While high-end simulations can train a variety of student types, the cost associated with these devices can be difficult to justify. Langhan (2008) states, "...before the medical education community embraces more technologically advanced (and hence more expensive) simulators, the role of lower-cost, less technologically advanced simulators must be evaluated" (p. 468). "What is the appropriate level of fidelity?" is the question that many within the medical training industry have asked. Langhan (2008) also comments that, "...there are no empirical prospective studies that support the use of more highly advanced modalities over lower-fidelity models" (p. 469). Langhan (2008) also suggests, "...ultra high fidelity task trainers and virtual reality computer-based programs, while impressive in their appearance, have not been demonstrated to be superior to low or moderate fidelity trainers" (p. 469).

Determining the fidelity needed for every training level is a major undertaking, but for this discussion the question has been scaled to a manageable size. Specifically, this effort will investigate the available simulators and simulations that contain a bleeding capability and evaluate their realism when compared to human physiology. This information will then be compared to the current groups of students that are using or could utilize bleeding simulation in their training in an attempt to identify what level of hemorrhage simulation fidelity is needed for training at the different levels of care.

Figure 1 graphically represents the basic hypothesis. By inspection and induction, a simple simulator is usually less expensive and therefore will more economically train a higher number of students. However, the less expensive simulators are also less sophisticated limiting the skill levels they can train. Conversely, the more sophisticated and generally more expensive simulators are designed with a tremendous number of clinical features and should be able to train an individual to a much higher level of expertise. The relationship between fidelity, cost and trainee skill levels should be linear. At this time, there is no clear way to determine what fidelity is appropriate for each level of required skill. This effort will attempt to answer some of these questions and overlay simulator capabilities where they fit best, across the levels of care. To start this evaluation, basic human physiology will be compared with current simulated physiology in various devices. A rubric will then be created to evaluate each device against the user requirements. The skills required at each level of medical care will then be examined and the rubric will be compared against the learning objectives. Since fidelity is not the

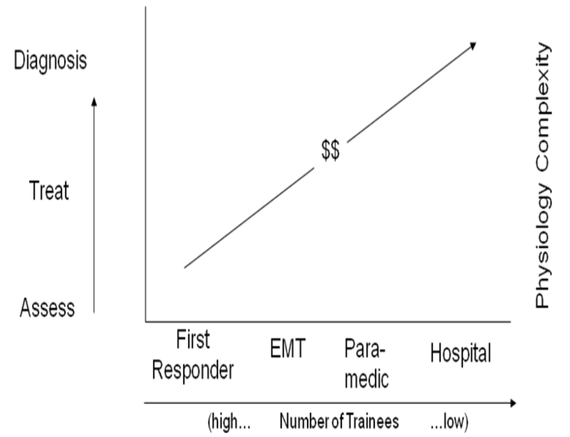

Figure 1: Hypothesis for the Analysis

only determining factor, the final decision will take into account other factors such as cost. Hopefully, the research and deductions herein can be used as a guide to aid in making an informed decision.

BASIC HUMAN PHYSIOLOGY

The human cardiovascular system is a complex network of arteries and veins controlled by many intrinsic factors. The core of the system is the heart. It acts as the central hub for blood flow both toward and away. As depicted in Figure 2, the arteries carry blood away from the heart and supply smaller and smaller vessels, until the end organ is reached. At this point there is an exchange of nutrients and, or waste. The blood is then collected by a series of veins which become increasingly larger as they progress back toward the heart. The major concept of this system is a 'closed loop' system. Blood is not simply left to wander or spill anywhere; it is contained within the organized network of blood vessels (Anderson, 2006).

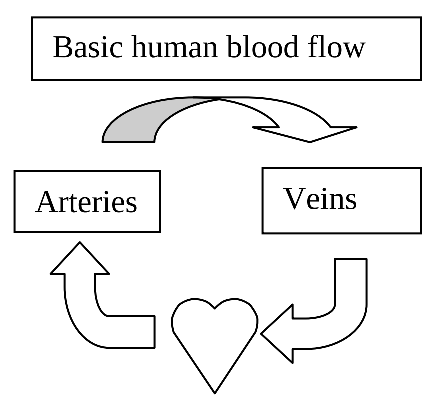

Figure 2: Normal, Simplified Human Cardiovascular System

As depicted in Figure 3, when the normal cardiovascular physiology is disrupted, by an amputation of an extremity for example, there is a multitude of chemicals released for short term control and long term regulation. The simplified version of the process is conservation. Peripheral blood vessels are constricted in order to decrease blood flow to extremities and increase central blood pressure. The blood vessels supplying the heart and brain are dilated, allowing more blood flow to these organs. The heart fills with more blood on each contraction to maximize output to the essential organs, the heart and brain ("Hypovolemic shock" n.d.; Kolecki, Menckhoff, 2008).

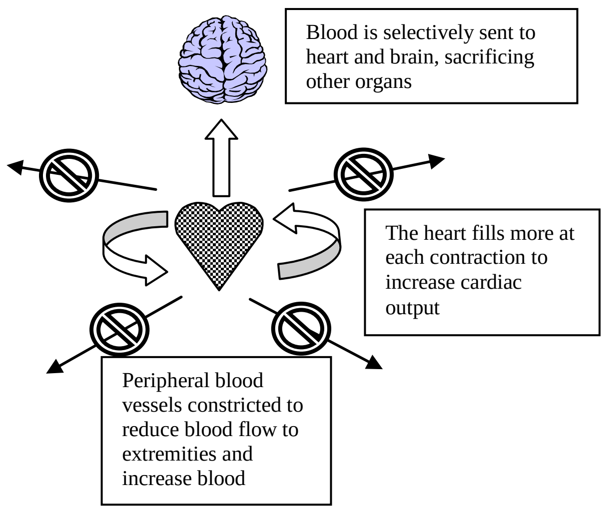

Figure 3: Human Response to Shock from Blood Loss

PROCEDURES/TRAINING AT DIFFERENT LEVELS OF CARE

Exsanguinating hemorrhage was chosen as the scenario for this evaluation because of its dire consequences in both the civilian and military medical environments. In the civilian realms, bleeding still has a high mortality rate. In the military, uncontrolled bleeding is the number one preventable cause of death on the battlefield (Cain, 2008). In order to focus the problem to a manageable size, bleeding control procedures were researched, and skills were identified at the pre-hospital and hospital levels of care.

At the pre-hospital level of care, skills of the first responder and the emergency medical technician (EMT) or paramedic were evaluated separately. The first responder is limited in what he or she can legally do, yet training these limited skills can save lives. The first responder can administer direct pressure, dressings, and pressure points. EMTs and paramedics on the other hand, have more treatments that they can administer. When confronted with life threatening hemorrhage, the escalation of treatment for an EMT/paramedic is as follows: direct pressure, dressing, pressure dressing, and pressure points. If those methods fail, and protocols allow, hemostatic agents and tourniquets are the final options to stop the bleeding. EMTs and paramedics can also administer fluid replacement therapy with saline-based volume enhancers and blood expanders. In either case, pre-hospital caregivers are limited by the equipment available in their vehicle or in their pack (Bledsoe, 1997; Buncome, 2008; Zeller, 2008).

Once the patient reaches the hospital, many more treatment options are available to the caregiver. At this level of care, skills of the doctor and surgeon were examined separately. The doctor follows the same progression of treatment as in pre-hospital care with additional pharmacological and fluid replacement options, such as whole blood and natural blood products. The surgeon expands care options with conventional surgery, cauterization, and embolization. Hospital caregivers also have access to high tech imaging capabilities which allow them to identify the exact problem area and focus their efforts on solving those problems. The hospital also has expanded capabilities that monitor the major systems of the body but require a much greater understanding of the interconnectivity of these biological systems. In the hospital, equipment limitations are typically not a major problem.

Even though many of the protocols appear to be the same across the levels of care, the cognitive abilities at each level of care differ significantly. In the pre-hospital arena, caregivers typically use pattern recognition to assess and treat the patient. Unless the caregiver is a physician, he or she does not diagnose a patient, but assess life threatening conditions and apply treatments to stabilize the patient. In the hospital, the doctors and surgeons use results of advanced testing to create a more detailed understanding of what is occurring throughout the body as a whole. This understanding of affected systems and possible complications leads to detailed diagnoses and definitive care. The hospitals also have the luxury of various pharmacological treatments as well as time to observe and react to changes in the system. Therefore, the requirements for physiological and pharmacological representations in medical training systems should vary significantly across the levels of care.

PHYSIOLOGICAL/PHARMACOLOGICAL REPRESENTATIONS IN MEDICAL SIMULATIONS

Different levels of required training create the need for a variety of medical simulation and training tools. The tools vary from simple representations to highly complex equations that have interdependent mathematical models to represent human physiology (Viceconti & Clapworthy, 2006). For example, the simplest representations of bleeding, typically found in first-person shooter games, dictate that if the patient receives a pre-determined number of wounds, regardless of location, death occurs, or:

$$Death = \sum Number\ of\ wounds\ (n)$$

$$Where\ 1 < n < 3$$

The next step in complexity is a simple time model where, if the bleeding is not stopped within a certain time, the patient dies. In another example, the representation of blood loss is driven by simple mathematical models where time is still a major component, but blood flow can vary or:

$$Blood\ loss = \int_0^t x\,dx$$

$$Where\ t = time$$

These two techniques are easy to understand and implement, but are not particularly accurate. Blood loss can be more accurately represented by Figure 4, where over time, one subsystem effects another subsystem of the body.

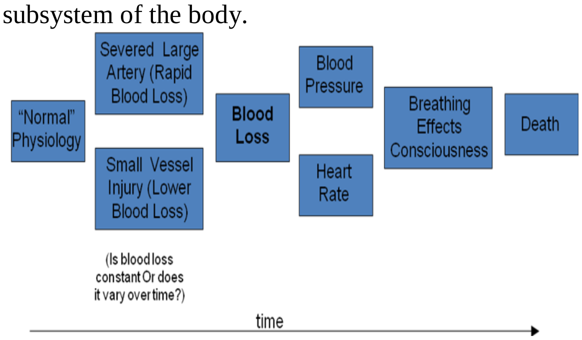

Figure 4: Simple representation of a game-based bleeding model.

For decades, scientists and researchers have been exploring how to accurately model the complex and interdependent physiological and pharmacological responses of the human body (Cobelli & Larson, 2008; Hoppensteadt & Peskin, 2002; Ottesen, Olufsen & Larsen, 2004). In 1972 Dr. Arthur Guyton and colleagues published an article challenging the current view of cardiovascular physiology. By applying simple engineering principles, Dr. Guyton and colleagues

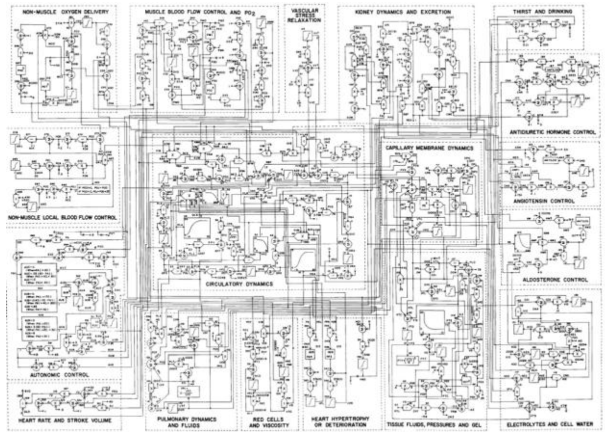

Figure 5: Arthur Guyton's Computer Model of the Cardiovascular System

created a computer model (written in FORTRAN) that became the basis for how blood pressure regulation and cardiac output were to be looked at for the future. Dr. Guyton utilized several hundred mathematical equations to relate long-term blood pressure regulation and cardiac output. A circuit analysis was done using pressure-flow and pressure-volume mathematical relationships that were later developed into a graphical analysis of cardiac output and venous return to the heart (Taylor, 2004; Montani, 2008). A portion of this circuit is shown in Figure 5 (Hall, 2000).

Dr. Guyton is well known as a pioneer in the field of medicine, especially physiology (Taylor, 2004). Consequently, his models have become the backbone of many simulation products. Many current simulators utilize the Guyton physiological models and extract the components they may need for their simulation product. (E. Fletcher, Executive Producer, Breakaway Ltd (Pulse!), personal communication, March 20, 2009). An example of a complex equation for bleeding is given below ("Blood Flow"):

$$F = \frac{\Delta P}{R} \qquad \text{(Darcy's law)}$$

$$R = \left(\frac{\upsilon L}{r^4}\right)\left(\frac{8}{\pi}\right) \qquad \text{(Hagen-Poiseuille equation)}$$

Where:

F = blood flow	υ = fluid viscosity
L = length of tube	r = radius of tube
R = resistance	P = pressure

The above equations represent a small example of the level of physiological complexity that might be required in any of the more realistic simulation and training devices.

MEDICAL SIMULATIONS

Medical simulation has historically been a small niche within the training community. In fact, the military often avoided accurate representations of casualties because it made their "real" simulations messy. This simplification was a disservice not only to the caregiver who was not afforded the chance to train his or her skills while preparing for war, but to the tactical commanders who were not trained to deal with the difficulties of managing casualties while still completing the mission. In fact, the civilian community has often been the leader in implementing simulation into medical training. Discussions with program managers at METI revealed that the company's Government systems sales are still only about 20% of overall sales.

Medical simulations are categorized as follows: personal computer (PC)-based training systems, task-specific trainers, full-body mannequin training systems, and surgical simulations. PC and mannequin based systems were evaluated for this exercise because they typically contain some type of physiological model. The evaluation of these technologies explores four different measures of simulation fidelity: visual representations, behavioral responses, haptics, and physiological models.

PC-based systems depict human patients by combining visual representations, physiological models, and behavioral responses. Mannequin-based systems include the same qualities as PC-based systems and also include haptics.

Visual representations typically involve the fidelity of the system itself, as well as how accurately the wound and bleeding are depicted. Behavioral responses refer to what the simulation does when the trainee intervenes. Does the system respond correctly and in a timely and clinically meaningful way? Haptics refers to the sense of touch and the realism of this interaction.

The PC-based systems are usually driven by a specific scenario and therefore have a limited scope. These systems are totally based on visual and auditory cues and typically have no haptic feedback. These are, however, very affordable and therefore lend themselves well to training large numbers of students. Examples of medical PC game base systems include: OneSAF, Pulse!, TC3 and OLIVE.

OneSAF is a constructive war fighter simulation that uses very simple models to represent wounding and time to death, where time to death is determined by a combination of the number of wounds and time. Pulse, TC3, and OLIVE were designed specifically for medical training and, therefore, have more complex and interdependent mathematical models (H. Mall, VP Engineering. ECS (TC3), personal communication, February and March 2009). Most of these models are proprietary and therefore, a basic description is depicted in Figure 6 (Mall & Frolich, 2006).

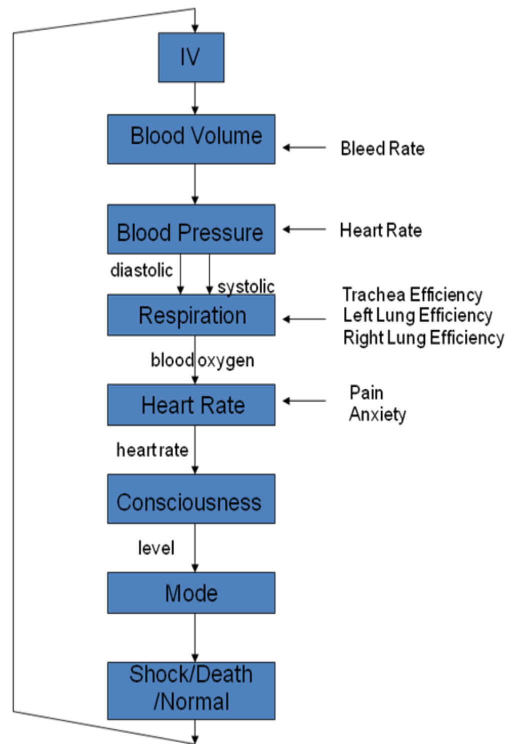

Figure 6: Representation of a Game-based bleeding model.

Mannequin Based Medical Simulations

Full-body mannequin based training systems typically depict the most complex representations of human physiology. This family of simulators is particularly useful for training both cognitive and psychomotor skills because a patient outcome can be achieved. In other words, the patient can improve, stabilize, or die. Full-body mannequin simulators are appropriate for both partial task training as well as team training, and they introduce the difficulties of taking care of a patient, not just a body part or computer screen. These systems are often based on very complex physiological representations and contain a great deal of internal and external computer hardware as well as various sensors, pumps, and other mechanical components. The complex physiology and physical attributes tend to make these systems very expensive. Some examples of these mannequins include: Laerdal's G3 and SimMan, Gaumards HAL, and METI's I-Stan and HPS. The manufacturers of all of these systems claim to have physiological models but the capabilities of these simulated physiologies vary significantly.

Two different models of Laerdal simulators were examined, the venerable SimMan and the emerging G3. The SimMan can train bleeding control, but physiological responses are the responsibility of the operator. The G3 marketing material claims physiological models, but discussions with the company suggest similar functionality to the SimMan (J. Hawkins, Southeast Regional Sales, Laerdal, personal communications, February 2009 and March 19, 2009).

Gaumard's newest human patient simulator is called 'HAL.' HAL is a full-size human patient simulator that allows participants the opportunity to practice various procedures. According to the company literature, this system is tetherless, but offers a wireless tracking log of up to six participants. HAL is advertised to have vital signs that respond to the current physiological condition and participant interventions. The unit comes with preprogrammed scenarios which can be modified or new scenarios can be authored. Optional packages include: arm/leg stumps that will bleed appropriately when compared to heart rate and blood pressure, trauma packages, and wound modules. The model used as the basis for HAL's physiology was not provided by Gaumard (Gaumard, 2008).

METI has touted its complex physiology for years from its early human patient simulator (HPS) to its newest simulator, the I-Stan (Van Meurs, Good, & Lampotang, 1997; Van Meurs, Nikkelson & Good, 1998). These models are self-compensating and they realistically adjust the vital signs along the continuum from healthy, through shock, to death. Many years of civilian and military use have validated these models which were originally based on Guyton's work.

ANALYSIS

In order to assess the fidelity against the levels of care, standards of measurement were required. Table 1 describes the rubric that was developed. The first four characteristics (physiological, visual, behavioral response and haptic fidelity) address the specific objective of this analysis. The others are given as examples of the complexity of the issue and as samples of other qualities they may be important when selecting medical simulation and training tools. Cost, although very important, was left out of this analysis and should be treated as an independent variable.

Once the rubric was established, the fidelity of each simulation was evaluated. Grades were then assigned based on various forms of available information. OneSAF, TC3, Olive, the Laerdal SimMan, METI I-Stan and HPS were evaluated using technical documentation and experience that was gained from previous developments. Pulse!, Gaumards HAL, and Laerdal G3 were evaluated through marketing literature and through interviews with company representatives. The grading results are represented in Table 2.

The next step in the analysis was applying a grading factor to each simulation factor based on the cognitive and skills requirements of each caregiver at the different levels of care. For example, physiological fidelity is much more important when training doctors and surgeons because they operate at a much higher cognitive level. The first responders and EMTs only require adequate signs and symptoms to assess a life threatening pattern so a complex physiology is not needed.

CONCLUSIONS

Part of the original hypothesis stated that a simple, or lower fidelity, simulator is usually less expensive and, therefore, will be more economical to train many students. A more sophisticated and generally more expensive simulator can train to a more advanced level. The analysis showed that the fidelity of human medical responses involves many factors; including physiological, visual, behavioral, and haptic fidelity and that the requirement for these features is quite dependent upon the needs of the training audience. The analysis also showed no direct correlation between overall fidelity and levels of care. If cost were not an issue at medical training locations, a more accurate human representation would be desirable, since it mitigates the need for an operator to become an expert in the complex interactions of anatomy and physiology.

This analysis concludes with four recommendations to assist in solving the identified problem Recommendation 1 is to establish an open source, standardized library of complex physiological models to reduce the cost of simulators making them more available for training all levels of care. While optimal, it may be unrealistic given the difficult and costly task of maintaining configuration control while protecting intellectual property rights. A simpler and more economical approach would be to standardize the desired inputs and outputs and allow the market to manage the details inside of each model. This would protect intellectual property and spur innovation while reducing the need for each new simulation technology to start from scratch.

Table 1: Rubric for evaluating medical simulations

	1	**3**	**5**
Physiological Fidelity	Time or state based: Little to no physiology. Death based on pre-determined number of wounds or time after wound without intervention	Semi-autonomous: Physiology based on actual algorithm, but scenario pre-determined by author.	Self compensating: Physiology based on human physiology. Systems interact. Outcome based on intervention
Visual Fidelity	Minimal to none Icons/colors Not clinically meaningful	Simple graphics; Cartoon, non-life like representations; Stiff, plastic, artificial	Life like animations, actions and skin
Behavioral Response Fidelity	Operator induced Subjective	Semi-Autonomous Pass/Fail	Timely, accurate and automated reaction to interventions
Haptic Fidelity	None	Tactile stimulation	Tactile stimulation with forced feedback
Operator Skill	Advanced training needed: Medical training and/or computer skills needed to program and/or author scenario.	Mild to moderate training needed: Basic medical background with intermediate computer skills needed to program and/or author scenario.	Minimal training needed: Basic computer skills for start-up and running scenario. Little to no medical training needed. Basic knowledge of simulator's system only.
Durability	Fragile: Simulator confined to laboratory only due to fragility of internal, external parts.	Covered: Simulator able to travel out of lab, but needs to be protected from elements.	Full field capabilities: Simulator able to withstand transportation and without regard to elements.
Users	One: Single user only.	Two-five: Two to five person scenarios.	More than five: Team based scenarios.
Refresh	>10 min: Resetting simulation and/or simulator takes more than ten minutes.	3-10 min: Resetting simulation and/or simulator takes three to ten minutes.	2 min or less: Resetting simulation and/or simulator takes two minutes or less.
After Action Review	None: No after action review available.	Pre-determined: After action review pre-determined by machine and/or author. Review based on yes or no, positive or negative.	Detailed: After action review customizable based on author. Measures quantity and quality along with time to response.
Availability	Limited: Limited to government or education affiliation.	Commercial: Available too many users, but contains proprietary information retained by manufacturer and/or developer.	Open source: Open to public with minimal limitations. Open source physiology and models.
Distributed Training	Fixed: Simulator confined to lab use only or PC.	Web based: Available on web globally. Limited by web access.	Mobile: Completely mobile and available to any location at any time.

Table 2: Analysis of Medical Simulations with respect to bleeding

	PC Based Gaming Environments				Mannequin Based Systems				
Criteria	**"A"**	**"B"**	**"C"**	**"D"**	**"E"**	**"F"**	**"G"**	**"H"**	**"J"**
Physiological Fidelity	3	3	3	1	3	2	3	4	4
Visual Fidelity	4	3	3	1	3	3	3	5	4
Behavioral/Response Fidelity	3	3	3	3	4	3	3	5	5
Haptic Fidelity	1	1	1	1	5	5	5	5	5
Operator Skill	3	5	3	1	3	1	3	3	4
Durability	1	1	1	1	3	1	3	4	3
Users	1	1	5	5	3	3	3	3	3
Refresh	5	5	3	3	3	3	3	3	3
After Action Review	3	3	3	3	2	2	3	3	3
Availability	1	1	3	1	1	3	3	3	3
Distributed Training	2	3	3	1	5	4	4	5	4

Table 3: Requirements at Different Levels of Care for Bleeding

	Levels of Care			
Criteria	1st Responder	EMT	Doctor	Surgeon
Physiological Fidelity	1	1	5	4
Visual Fidelity	4	4	3	2
Behavioral/Response Fidelity	2	3	3	4
Haptic Fidelity	4	4	2	3
Operator Skill	5	5	5	5
Durability	5	4	2	2
Users	1	2	3	5
Refresh	5	5	3	3
After Action Review	3	3	5	5
Availability	3	3	3	3
Distributed Training	3	3	2	2

Recommendation 2 is for trainers searching for medical simulation solutions to perform a detailed and objective task and cognitive analysis on their programs of instruction, perform a market survey of possible solutions, and then prioritize and crosswalk their training requirements against the available simulation capabilities. This analysis would identify when higher fidelity models are necessary based on terminal learning objectives and would remove some of the subjectivity that currently plagues simulation purchasing decisions. By performing the legwork prior to the purchase decision, the proper fidelity can be applied which will reduce cost and mitigate the need for an operator to become an expert in running simulators that are too complex for the training task. This requirements analysis model would be a fine start for an automated analysis tool or expert system that would allow easier evaluations across different tasks. Too often, marketing literature or personnel convince training organizations that their "one size fits all" simulation is optimal for all training scenarios. The risk of this approach is in allowing salesmanship to override educational need. One point this exercise has made very clear is that there is no "best" medical simulation for all levels of training.

Recommendation 3 is to develop a standardized protocol for the storage, recording, and transfer of data, including the development of a standard taxonomy. In other words, create a common verbal and technical language that covers medical simulation.

Although there are many factors driving simulation in medicine, there is some resistance. One concern is the transfer of knowledge. Experts have stated, "the knowledge translation from the simulated environment to the clinical world has not been fully explored" (Langhan, 2008, p. 468). Recommendation 4 is to conduct further research in the area of validity. Once the transfer of knowledge utilizing a simulator can be validated, it should make the acceptance of simulation in medical education more mainstream (Kobayashi, Patterson, Overly, Shapiro, Williams, 2008). A small subset of medicine has already embraced this technology. The field of Anesthesiology, for example, uses simulation for training during education (Matveevskii & Gravenstein, 2008). Validation will not be a trivial task; however, it is a challenge that deserves attention.

To further develop this analysis model, expert trainers at various levels of care should be consulted to determine the fidelity issues they face every day. Their inputs should be compared to the critical learning tasks of various medical curricula to validate and expand the model. This expansion could easily result in an expert system that simplifies the answer to the question: "What fidelity simulator is needed to teach a specific medical course?"

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