

## Human Factors Engineering

# Using Simulation-Based Training to Improve Patient Safety: What Does It Take?

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Simulations have been used as early as 1910 as a means to train both persons and teams to reduce errors and improve safety.<sup>1</sup> Commercial aviation and the military have invested heavily in the use of simulation-based training because it offers a realistic, safe, cost-effective, and flexible environment in which to learn the requisite competencies for the job.<sup>2,3</sup> Given its purported success in these areas, the use and application of simulations as a training tool has spread to a number of other domains, such as business, education, and medicine.<sup>4</sup> The focus of this article is on providing research-based guidelines extracted from the military and commercial aviation communities' experiences in designing and delivering simulation-based training for application in the health care community.

Although the popularity of simulation-based training has grown during the past decade, using simulation as a part of training is not a panacea. Our review of the team training literature in health care, which we conducted in 2004,<sup>5</sup> showed, for example, that simulation-based training is used to improve team performance (for example, anesthesia crisis resource management training<sup>6</sup>). However, it appeared that simulation-based training programs early on either focused on the engineering component of training (that is, the simulator itself) or took a more balanced approach in which simulation is studied in the context of a learning methodology.<sup>5</sup> For example, in a study conducted by Howard and colleagues,<sup>6</sup> the training program focused more on how trainees use the simulator rather than on how the team should work together to respond to the situation.

## Article-at-a-Glance

**Background:** Through simulations health care workers can learn by practicing skills taught and experiencing mistakes before interacting with an actual patient. A number of areas within the health care industry are currently using simulation-based training to help individuals and teams improve patient safety.

**What Is Simulation-Based Training?** The key components of simulation-based training are as follows: performance history/skill inventory, tasks/competencies, training objectives, events/exercises, measures/metrics, performance diagnosis, and feedback and debrief.

**What Does It Take for Simulation-Based Training to Be Effective?** To be effective, simulation-based training must be implemented appropriately. The guidelines are as follows: understand the training needs and requirements; instructional features, such as performance measurement and feedback, must be embedded within the simulation; craft scenarios based on guidance from the learning outcomes; create opportunities for assessing and diagnosing individual and/or team performance within the simulation; guide the learning; focus on cognitive/psychological simulation fidelity; form a mutual partnership between subject matter experts and learning experts; and ensure that the training program worked.

**Conclusion:** The health care community can gain significantly from using simulation-based training to reduce errors and improve patient safety when it is designed and delivered appropriately.

Yet research indicates that simply adding simulation to training does not make it more effective nor will it guarantee that trainees learn more, better, or the right things.<sup>7</sup> Rather, simulation-based training must be designed and delivered on the basis of what we know about the science of training<sup>8</sup> and learning.<sup>9,10</sup> This science provides a blueprint on how to design, deliver, evaluate, and transfer training systematically.<sup>11</sup>

This article's purposes are as follows:

- To highlight the key features needed so as to promote standardization of simulation-based training
- To make designers of health care simulation-based training aware of its possibilities
- To use research-based guidelines to promote dialogue and collaborations between learning, health care, and simulation experts

## What Is Simulation-Based Training?

Simulation-based training provides opportunities for trainees to develop requisite competencies through practice in a simulated environment that is representative of actual operational conditions; trainees receive feedback related to specific events that occur during training.<sup>12</sup> There is a wide array of simulation types that can be used to train teams (for example, Medical Emergency Teams<sup>13</sup>) in health care.<sup>14</sup> Simulations can range from low-fidelity role playing exercises (for example, an event/scenario is reenacted) to part task trainers (for example, training of endotracheal intubators) to high-fidelity full-motion simulations (for example, trainees conduct a realistic surgical procedure including prebrief, task completion, and debrief).

Figure 1 (page 365) presents the key components or cycle of simulation-based training.<sup>15</sup> Seven interrelated and critical stages make simulation-based training work. The cycle begins with determining the skills held by trainees and their previous performance data (circle 1). This assessment shapes the next step. Step 2 concentrates on identifying the tasks and competencies that will be the focus of training (circle 2). Once these are determined, training objectives (that is, learning outcomes) are specified (circle 3). Training objectives can be either task-specific (for example, trainees will demonstrate their ability during open-heart surgery) or task-generic (for example, trainees will make better decisions

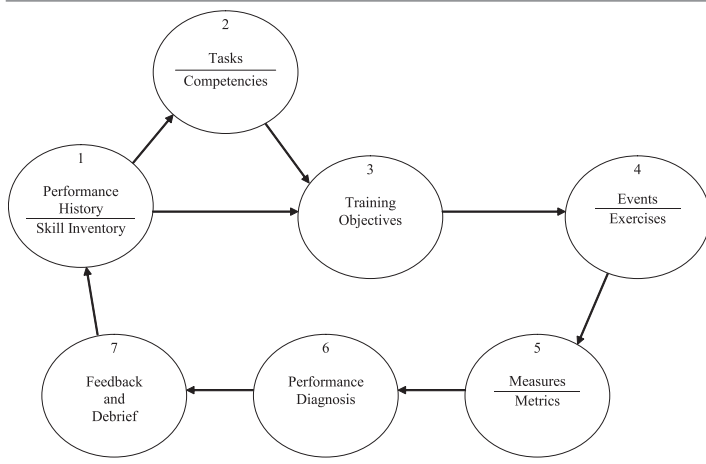
in the operating room). Steps 2 and 3 can be accomplished by various task analysis techniques (for example, cognitive task analysis<sup>16</sup>; team task analysis<sup>17</sup>).

The outcomes of steps 2 and 3 serve to drive step 4 with the development of appropriate scenarios (that is, "trigger" events/exercises, based on critical incidents data) to be embedded into the training (circle 4). Scenarios must be designed and scripted to ensure that the requisite competencies are elicited during the simulation. We submit that in simulation-based training, the "scenario is the curriculum." The scenario creates the environment on which the trainee is guided, informed, diagnosed, and provided feedback on expected learning outcomes. Therefore, the scenario (and the "trigger" events) serves as a critical component (not the only one) in the cycle. It must be designed with learning outcomes in mind and with creating opportunities for performance measurement. So in step 5, performance measures and standards are developed to diagnose if the trained competencies are learned and applied appropriately. Performance measures should be designed such that they are able to collect data pertaining to both outcomes (for example, did the physician complete the surgery?) and processes (for example, did the physician make the diagnosis correctly?). During the next step (circle 6), actual performance data are collected and compared against the standards previously stated. Performance data can be collected in a simulated or real-world environment. The performance data form the basis for providing feedback to trainees (circle 7). Finally, the information gathered on trainee performance (for example, skill inventory, performance history) must build on previous training programs (circle 1) to modify future training programs. Taken together, these stages create the ingredients for effective simulation-based training.

## How Is Simulation-Based Training Being Applied in Health Care?

Although the military and commercial aviation are likely the largest investors in simulation-based training, the health care community has begun to more frequently use simulations as a means to train individuals and teams. Sim One, one of the first computer-based mannequins used in the health care community, dates back as early as the 1960s.<sup>18</sup> Through simulation, health care

## Components of Simulation-Based Training



**Figure 1.** Seven interrelated and critical stages make simulation-based training work. Adapted from Oser R.L., et al.: *Enhancing human performance in technology-rich environments: Guidelines for scenario-based training*. In: Salas E. (ed.): *Human/Technology Interaction in Complex Systems*, vol. 9. Greenwich, CT: JAI Press, 1999, pp. 175–202.

workers can learn by practicing skills taught and experiencing mistakes before ever interacting with an actual patient.<sup>19</sup>

One of the most widely documented uses of simulation-based training to help persons and teams improve patient safety is anesthesia crisis resource management training (a form of team training first developed for aviation<sup>6,20</sup>). Using crisis management scenarios (with varying patient diseases and equipment failures) obtained from a critical incidents database, anesthesia teams perform a number of scenarios in a simulated environment followed by a debriefing of their performance (for example, in Salas et al.<sup>5</sup>).

Less technologically based yet still a form of simulation-based training is the objective structured clinical examination (OSCE) used for training medical students. In a typical OSCE, medical students encounter standardized patients (SPs; trained individuals who accurately simulate various patient illnesses in a standardized manner<sup>21</sup>). OSCEs and SPs are generally used to teach and evaluate clinical skills acquisition in medical students and residents using checklists, global ratings, or both. Simons and colleagues<sup>22</sup> reported that 97% of medical schools in 1997 were using SPs and that 72% were using SPs in conjunction with an OSCE.

Computer-based simulators are being used to improve patient safety in radiology<sup>23</sup> and to assess the effectiveness of various critical incident training strategies.<sup>24</sup> In a number of surgical areas (for example, sinus, orthopedic, prostatic), simulators and virtual reality have been used to train surgeons on the requisite technical skills as well as dexterity in the operating room.<sup>25–27</sup> Cardiology has used simulations for more than 10 years, with simulations ranging in fidelity from audiocassettes to full patient simulators.<sup>28</sup> Research suggests that these simulations have improved performance with actual patients.<sup>29</sup> Training using virtual reality in gastroenterology has also demonstrated improved performance by doctors.<sup>30</sup> Also, simulation-based training has been used to improve patient safety in neonatal resuscitation.<sup>31</sup> While widely being used, one of the

biggest concerns cited by the health care community (and others) using simulation-based training is the lack of fidelity of some of the simulations (for example, neonatal mannequin).<sup>31,32</sup> We encourage the reader to see Cooper and Taqueti<sup>33</sup> for more information on the history and use of simulators in health care.

For all the use of simulation-based training in the health care community, an account of a deeper understanding of how it can most effectively contribute to patient safety has yet to be provided.<sup>5,28</sup> In addition, two issues appear to characterize simulation-based training in health care. First, it appears from much of the literature that it focuses more on training technical skills rather than the interpersonal skills as suggested. For example, our review of the crisis (or crew) resource management literature<sup>5</sup> indicated that several training programs stated that their purpose was to improve teamwork skills. However, the actual training program focused more on the technical skills needed to operate the simulation rather than the teamwork skills (examples appear in the literature<sup>6,31,34</sup>).

Second, it is worrisome that the literature provides little guidance on how to design and deliver simulation-based training in health care. Several major works cite the need for more extensive training but do not provide

in-depth information about how to get there. For example, Barach and Small<sup>35</sup> suggest that An Organisation with a Memory,<sup>36</sup> a report on learning from adverse events in the National Health Service, takes an “ambivalent approach to team research and training”<sup>(p. 1684)</sup> in that it does not discuss the role that the social sciences play in safety. This implies that although training should be a focus, it is buried beneath a focus on individual-system dynamics. In another study of reporting systems, Dineen and Walsh<sup>37</sup> reported that fewer than half of the respondents participating in their research had received specific training on risk management. Although training has occasionally been designed systematically (examples appear in the literature<sup>38</sup>), most of the research within health care has not adequately addressed the methodology needed to effectively implement training.

## What Does It Take for Simulation-Based Training to Be Effective for Patient Safety?

Although there is some evidence that simulation-based training works,<sup>39</sup> it is important to remember (again) that simulation is just a tool to enhance learning and training. Like any tool, to be effective it must be implemented appropriately. Satish and Streufert<sup>40</sup> highlight the role that simulation may play in both a training and assessment capacity within the health care community. They recognize that for simulation-based training to be effective it must (a) be built upon underlying theory (they use complexity theory), (b) use preplanned, structured exercises, (c) assess performance, and (d) provide feedback. However, we found little in the health care literature that offers guidance on how to properly achieve these four steps—and, thus, learning effectiveness.

Now, the reader may get the idea that Satish and Streufert’s four steps of simulation-based training discussed are simple procedures and may therefore conclude that “we in medicine are doing this already.” We submit that there is more than meets the eye regarding how simulation-based training must be designed and delivered, which led us to develop the guidelines presented here.

Using what we know about the science of training<sup>8,38</sup> and learning,<sup>9,10</sup> and what has been learned from our experiences with the use of simulation-based training in

aviation and military environments,<sup>2,41</sup> we developed guidelines of what it takes for simulation-based training to be effective<sup>42</sup> (Table 1, page 367).

### Guideline 1. Understand the Training Needs and Requirements

The first step in designing any training program is to understand the requirements of training. This includes determining who needs to be trained, what tasks they need to be trained on, and what competencies are needed to effectively perform those tasks.<sup>43</sup> Three types of analyses should be conducted—organizational analysis, job/task analysis, and person analysis. The organizational analysis helps to establish the components (for example, norms, climate) and resources and constraints (for example, monetary) of the organization that may impact how training is delivered.<sup>43</sup> The job/task analysis helps specify the job description (for example, essential work functions, resources needed), task specifications (specific tasks that need to be completed), and task requirements (competencies required). Finally, the person analysis is conducted to determine who needs to be trained and what needs to be trained.<sup>38</sup> Once the training requirements are understood, the information acquired will lead to the development of the learning objectives. The type of simulation can be determined on the basis of the learning objectives and what the organization hopes to get out of training. For example, case studies may be appropriate if the purpose of training is to change trainees’ knowledge and attitudes, whereas part-task trainers or full-motion simulations may be more appropriate for training knowledge and skills.<sup>44</sup>

### Guideline 2. Instructional Features, such as Performance Measurement and Feedback, Must Be Embedded Within the Simulation

The science of simulation-based training centers on embedding key instructional components—it must create a learning environment. For example, in an event-based approach, key events are defined a priori (see Guideline 1) to act as cues that “trigger” essential actions and behaviors.<sup>1</sup> These events serve as learning opportunities and are provided at various times throughout the simulation.<sup>45</sup> Consider, for example, the use of OSCE and SPs to train medical students. An analysis is conducted

**Table 1. Guidelines for Designing and Delivering Simulation-Based Training**

- Guideline 1. Understand the training needs and requirements
- Guideline 2. Instructional features, such as performance measurement and feedback, must be embedded within the simulation
- Guideline 3. Craft scenarios based on guidance from the learning outcomes
- Guideline 4. Create opportunities for assessing and diagnosing individual and/or team performance within the simulation
- Guideline 5. Guide the learning
- Guideline 6. Focus on cognitive/psychological simulation fidelity
- Guideline 7. Form a mutual partnership between subject matter experts and learning experts
- Guideline 8. Ensure that the training program worked

to determine the diagnosis and treatment skills needed by medical students to effectively handle an incoming patient. Patient's symptoms are then simulated by the SP, thereby serving as "trigger" events to elicit specific behaviors from students to indicate their knowledge, skills and attitudes. Especially useful within high-consequence domains where errors can be costly, simulation-based training allows trainees to practice and receive feedback regarding their performance without the risk to patients and with the means of improving patient safety. Therefore, unless instructional features, such as performance measurement, videorecording, and systematic observations of targeted behaviors, are embedded into the simulation, opportunities for learning will not be available for trainees (see Tobias and Fletcher<sup>46</sup>).

#### Guideline 3. Craft Scenarios Based on Guidance from the Learning Outcomes

As noted, scenarios must be carefully laid out and storyboarded before the training begins to provide trainers and researchers more control over what competencies are being trained (that is, standardization), how they are presented to participants, and when. Scenarios should be developed such that they are as realistic (don't ignore the small details) as possible, have varying levels of

difficulty, allow trainees to respond in more than one way, and allow trainees to demonstrate the knowledge and behaviors of interest on multiple occasions.<sup>47</sup> This allows the immersion of the trainee without necessarily having the highest fidelity<sup>9</sup> (see Guideline 6). If scenarios are well crafted, trainees will be engaged, will gain experience, and will develop accurate mental models (or templates) of what to expect and how to respond if a similar situation is faced on the job (transfer of training). In addition, this experience gives trainees higher confidence levels when responding to similar situations,<sup>48</sup> improved memory recall, and better and quicker decision making.<sup>49</sup> The use of content-valid scenarios is critical in environments (such as health care) where errors, if not corrected in a timely manner, can have catastrophic consequences and also where some procedures are rarely performed.

#### Guideline 4. Create Opportunities for Assessing and Diagnosing Individual and/or Team Performance Within the Simulation

Performance measurement drives the simulation—without assessment and feedback, learning may be hindered, and simulation-based training becomes merely a simulation. We know that diagnosis is critical for learning.<sup>50</sup> It has been argued that simulation-based training will only be effective to the extent that trainee competence can be assessed.<sup>39</sup> Three criteria must be met for this assessment. First, measurement opportunities must be provided that ease the burden on those responsible for performance measurement. In other words, the use of prescribed, learner-focused scenarios ensures that the significant competencies are being prompted. Instructors (or observers) therefore know a priori when these "trigger" events will occur and can observe and record performance.

Second, a basis for diagnosing performance trends and providing feedback must be established, which is more challenging than one would expect. For example, automated technology as a part of a simulation is an excellent way to capture performance outcomes (for example, time, errors). This technology is limited, however, in that it can not easily capture data related to the real-time processes that trainees progress through to attain these outcomes (for example, communication,

decision making). This is especially true when assessing team performance because teams are very dynamic in nature and teamwork processes are difficult to capture. For example, during periods of high workload (such as those experienced by trauma teams) teams have been argued to communicate and coordinate implicitly, making it impossible for a simulation-based system to detect. A human observer, on the other hand, will be more able to make inferences from observing the behaviors to diagnose teamwork issues using checklists or observation forms (for example, TARGETS<sup>51</sup>; SAGAT<sup>52</sup>). It is recommended that training programs use at least two observers or evaluators who can more readily diagnose performance and provide strategies for improving future performance.<sup>53</sup> The use of evaluators to provide ratings, unfortunately, is not free from errors and biases. Training designers must focus on improving the reliability (are evaluators' ratings consistent with each other and are each evaluator's ratings consistent over time?) and validity (are evaluators rating the right things?) of evaluators though training to ensure consistency and accuracy (see descriptions in the literature<sup>54-56</sup>). A third and final challenge faced by training designers is ensuring that multiple measurements are taken throughout the simulation to gather a truly representative picture. Again, this is especially important when related—moment-to-moment—data are of interest.

#### Guideline 5. Guide the Learning

As the familiar saying goes, “practice makes perfect.” Research suggests that experience with different situations (either simulated or real) will improve performance by generating knowledge structures within a meaningful context—that is, accurate and efficient mental models can be established that facilitate the learning of a complex task.<sup>39</sup> However, practice alone (for example, task exposure) is not enough. Rather, practice must occur in conjunction with training<sup>57</sup> and be guided to ensure that trainees learn the correct behaviors needed for the real-world task environment.<sup>41</sup> In guided practice, trainees are led through the scenarios (for example, guided to errors) and provided with instructional or computer-based support to help them understand the problem and develop strategies for improving performance. For example, an emergency room simulation may

involve a seemingly stable patient deteriorating rapidly to a state of cardiac arrest. The emergency room team must quickly respond to save the patient's life.

Scenarios may also be crafted to trigger the wrong behaviors so that trainees can experience these errors and observe the consequences so that those behaviors can be recognized in the future.<sup>58</sup> Instructors are on hand to teach trainees corrective strategies so that they may better respond to similar situations. Research has shown that guiding trainees to errors led to better performance than those who were not guided (examples appear in the literature<sup>59,60</sup>). Furthermore, as noted, guided practice will facilitate the capture of appropriate team processes. The final component of guided practice is the receipt of diagnostic and timely feedback.<sup>61</sup> Feedback should be provided to both individuals and teams that identifies both positive and negative aspects of performance so that trainees may adjust their strategies as necessary.

#### Guideline 6. Focus on Cognitive/Psychological Simulation Fidelity

A common assumption regarding simulations is that the more “bells and whistles” (that is, higher physical fidelity) the better the training. However, more important than just using a high-fidelity simulation is using a simulation in which the fidelity meets the training requirements. There are three types of fidelity to consider. First, environmental fidelity relates to how well the simulation replicates sensory cues in the environment (for example, motion, visual).<sup>44</sup> Second, physical fidelity relates to how closely the simulation mimics the real-world environment<sup>62</sup> (for example, realistic patient response, equipment interfaces, and environmental factors such as time pressure or stress). Although simulations high in physical fidelity offer some added realism and are often liked by trainees, the psychological fidelity of the simulation is just as, if not more, important for learning to take place.<sup>63</sup>

Research suggests that as long as the psychological fidelity is high (that is, the simulation requires progression through the same cognitive processes as those that are required on the job), learning will still take place.<sup>64</sup> For example, the use of low-physical but high-psychological fidelity simulations have been used to train complex skills (such as decision making) that have been shown to transfer to the job (for example, Gopher, Weil,

and Bareket,<sup>83</sup> Prince and Jentsch<sup>65</sup>). On the basis of what is learned from the team and cognitive task analyses, the level of fidelity should be determined by both the cognitive and behavioral requirements of the task.<sup>2</sup> Applying this guideline to the health care community, consider the use of simulation to train an intensive care unit team to effectively and cooperatively respond to the needs of a patient. A low-fidelity computer-based simulation can be used in which members are presented with a set of patient symptoms and asked to make appropriate diagnoses and recommend treatment. Asking trainees to review a case study by discussing the steps they would take and decisions that would be made is another example of a low-fidelity simulation.

#### Guideline 7. Form a Mutual Partnership Between Subject Matter Experts and Learning Experts

Learning is a behavioral/cognitive event. When designed and implemented correctly, training should impart long-lasting change in trainees' knowledge, skills, and attitudes by creating a context in which these competences can be practiced, assessed, diagnosed, remediated, and reinforced. Designing and delivering training appropriately requires cooperation between subject matter (or task) experts and learning experts—those who know and can apply the science of learning. Subject matter experts (for example, surgeons, anesthesiologists, nurses) are an integral part of the training design—they are a great source of task domain knowledge and can easily articulate task-related needs and requirements.<sup>7</sup> However, clinical experts do not necessarily have the knowledge and skills to develop and implement a sound learning environment—thus the need for learning experts emerges. It would be unrealistic to think that clinical experts know how to design and deliver training, just as it is unrealistic to think that learning experts have the necessary domain-specific knowledge to develop realistic scenarios. Completing this process without the help of one another will lead to an ineffective training program—and an inability to meet the training objectives. It is important that the health care community foster the collaboration of both parties.

#### Guideline 8. Ensure that the Training Program Worked

Following the delivery of simulation-based training, it is necessary to determine if the training program

worked. To obtain the most complete picture of training's effectiveness, it is important that organizations take a multilevel approach to evaluation. One of the most widely used training evaluation typologies is that established by Kirkpatrick<sup>66</sup> and later expanded by Alliger and colleagues.<sup>67,68</sup> It is suggested that training be evaluated at four levels—reactions (did trainees like training and find it useful?), learning (did trainees learn from training [knowledge and skills] and is knowledge retained?), behavior (do trainees apply what they learned on the job?), and results (did training impact the organization?).

We acknowledge that evaluating training at all four levels may be resource intensive and that many organizations evaluate training at the lower levels, namely reactions or learning.<sup>36</sup> However, a multilevel approach is the only way to truly assess training's effectiveness. Although some persons in the health care community are taking this multilevel approach, and some data look positive,<sup>6</sup> we believe that more systematic and rigorous evaluations are needed to determine its true effectiveness at improving patient safety.

## Conclusion

Simulation-based training can be effective in improving patient safety. Although more robust multilevel evaluations are needed, initial data regarding its effectiveness are encouraging. The health care community can gain significantly from using simulation-based training to reduce errors and improve patient safety when it is designed and delivered appropriately.

Yet data should not be misinterpreted to suggest that simulation in and of itself leads to learning. Simulation is just a tool to enhance training, and it alone will not lead to improved patient safety. We encourage the health care community to move beyond the engineering aspects of simulation (for example, focusing on how to use the simulator) to the instructional strategies that it serves to enhance. To do this, training designers must focus on the proven principles of learning and training. Simulation-based training offers a flexible architecture that provides trainees with opportunities to practice the learned competencies in a safe environment, allows for the collection of performance data, and provides feedback regarding performance. **L**

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