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SYNTHETIC ENVIRONMENTS FOR SKILLS TRAINING AND PRACTICE

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Overview

Today's technologies—from Web 3.0 and beyond to mobile devices to game engines to immersive and augmented virtual systems—offer great potential for students to train and practice the physical and cognitive components of hands-on social interaction skills in safe, diverse, and controllable contexts. Systematic training and practice opportunities in the real world are, at best, difficult to set up in typically resourced educational settings, but for many skills it is critical to validate students before they experience uncontrolled and unseen situations. Synthetic environments (SEs), the term used in this chapter, involve a human–computer interface that facilitates the student interaction with and engagement in computer-generated activities and resources, whatever the platform. SEs offer the potential to deliver systematic learning opportunities with (virtual) objects and people in precisely controlled, dynamic situations. SE paradigms allow for the sophisticated, objective, real-time measurement of students' behaviors and training outcomes, such as changes in performance or focus of attention (Parsons, 2015a). Continual cost reductions in, and improved capabilities of, SE technologies promise the advancement of more accessible, usable, and relevant SE applications to address an increasingly wider range of physical and cognitive training and practice conditions (Parsons, 2016; Parsons & Phillips, 2016; Bohil et al., 2011).

This chapter discusses the development, presentation, and measurement of SEs for training and assessment. We have been involved with the design, implementation, study, and application of many SEs, and, as a result of our experience, we have come to view SEs as supporting a cycle that relates motivation and retention to performance as portrayed in Figure 11.1. The engaging nature of well-designed SEs encourages students to explore the environment and demonstrate behaviors

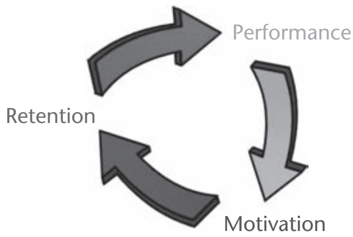

FIGURE 11.1 Benefits of engaged learning

as they would or should in a real situation. This performance leads to retention of content, but also motivation to continue learning that extends the cycle. One of the theoretical bases for use of SEs in training and assessment is the constructivist approach advocated by Mayer (2009) and others. We view learning as an active role taken on by students, in environments that emphasize realistic tasks and dynamic feedback and guidance. Further the cognitive components of gaining knowledge and behavioral aspects associated with learning a skill suggest that the careful design of SEs is critical to creating a platform for successful learning.

SEs have traditionally been used for training of hands-on skills. Early systems focused on the physical elements of these skills, using costly setups that were nevertheless necessary to train on skills that were logistically complex or outright dangerous (Stone, 2001). Some subsequent SEs have continued this trend, particularly in surgical simulation (McElhinney et al., 2012). Others have focused more on strategies and procedures, using representative if not fully realistic physical manipulation, but using the rapidly advancing technology intelligently and applying it across a huge range of domains (Hale & Stanney, 2015).

In contrast, our more recent work reflects a growing trend in SEs in their use of intelligent virtual human (VH) agents for social and interaction skills training. These systems consist of artificially intelligent characters that have realistic appearances, can reason and behave much like people in similar situations, and can express themselves both verbally and non-verbally (Hubal, 2008a; Hubal & Frank, 2001; Hubal et al., 2007; Kenny & Parsons, 2011; Parsons, 2011b).

No matter the domain, SEs afford desired training features such as standardization, potential cost reduction, dynamic tailoring to the individual student, readily adapted content, and faithful administration of assessments. The remainder of this chapter discusses these and other features of SEs as they apply to skills training and assessment.

Development

A key component to training and assessment through SEs is development of educational materials, including resources and activities. Material development is by now quite well understood. The use of computer-based instruction for strict drill and practice and straight conversion of print-based materials to electronic form is, thankfully, past; materials designers now understand how to employ advanced technology in their applications. Here we offer insight gleaned from past experience designing and evaluating SE-based skills training applications.

Learning Objectives

As students interact in the virtual situations that are portrayed by the SE the effects and consequences of their actions (positive or negative) can be carefully assessed. The realism of interactions can be varied and the SE can control the pace and complexity of exposure to learning contexts. This allows for a degree of individualized design with regard to the SE-based practice of skills.

It is critical the materials designer first understand what is to be learned. Commonly, these goals are called learning objectives (LOs). LOs should be definable and measurable. Because they can be defined and measured, they can be labeled, saved, and reused. The need is for the designer to develop materials that help the student meet LOs. The designer should carefully weigh alternative approaches that meet the requirements. For instance, objectives that are well-defined, structured, and well-understood, such as gaining skills at troubleshooting machines (Hubal, 2005), can be met using structured, ordered materials with content-relevant help. In contrast, objectives that are ill-defined, unstructured, or poorly understood, such as gaining interaction skills (Hubal & Frank, 2001; Hubal, 2008a), can better be met using more free-form instructional materials with context-sensitive help.

Further, there should be a train-up of skills, increasing the ambiguity, complexity, uncertainty, and/or volatility of what is meant to be learned (e.g., the "task classes" of van Merriënboer et al., 2002). Ideally, an intelligent tutoring system would control this scaffolding (Jackson et al., 1998; Lane & Johnson, 2008), providing decreased assistance as the difficulty—and student competency—increases. Put another way, the SE should support students as they move from orientation, in which relatively simple problems are presented, to inquiry that encourages exploration and understanding of the complexity of the content, to policy formulation that demands that students develop rules and heuristics to perform successfully on a given problem and generalize to new ones (Milrad et al., 2003). As will be expanded further below, types of assistance that systems can provide to support students in achieving LOs include direct, extrinsic support (tutoring, highlighting, help functions), encouragement to reflect on learning that often leads to deeper understanding as well as realization of gaps in knowledge, and internal or intrinsic support (such as reducing task complexity or providing hints within the flow of the simulation) (Wray & Woods, 2013).

Tie to Strategic Needs

Effective learning needs to be tied to the needs of the students. Though this statement appears straightforward, it underlies an important ingredient to training success: students will be motivated to learn if they are able to immediately envision ready application of the knowledge and skills gained (Garris et al., 2002). The needs of students almost always extend beyond basic skills. As the basic skills are acquired, the SE must adapt, such as increasing the difficulty (to address more advanced LOs). Features such as materials reuse, modular design, and adaptive presentation can ensure that new and evolving knowledge and skills can be acquired just-in-time. Ease of distribution is also important; convenient access to learning content not just in the classroom but also across the Internet and via mobile devices, with encouragement provided through social media, implies a greater ability to access new knowledge and to practice skills flexibly, just-in-place.

Gain-Practice-Demonstrate

A staged model for providing learning opportunities uses a gain-practice-demonstrate framework (adapted from Frank et al., 2000 and Hubal & Pina, 2012). The concept holds that students first gain whatever knowledge is specific to the topic, then they acquire basic skills and iteratively practice them, ultimately demonstrating competence or mastery on performance measures during assessments. Figure 11.2 shows this approach schematically.

Becoming knowledgeable in to-be-learned material implies acquiring declarative information about concepts, capabilities, and characteristics relevant to what is being studied. Declarative knowledge is factual, overt, well-understood, basic information about skills and contexts. This part of the process is relatively passive; knowledge can be gained, for instance, by absorbing a presentation or through reading. But it forms the basis for skills acquisition. Acquiring a skill is learning techniques and procedures, at first a relatively passive endeavor but becoming active as students perform the skills. Later stages of acquisition can be achieved in an SE, as can the practice (often called proceduralization) through which the student internalizes techniques and procedures. Procedural abilities are thus gained during acquisition, and they are automated during practice. For instance, driving a vehicle first requires knowledge of clutches, exhaust systems, road signs, rights

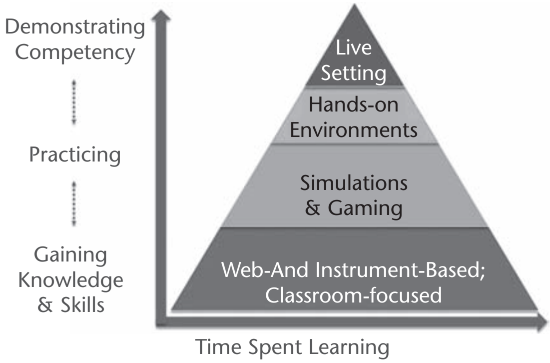

FIGURE 11.2 Gain-practice-demonstrate approach

of way, etc. With practice, this knowledge becomes routine, a skill (often, as in this case, largely a motor skill) that demands decreasing exertion to accomplish. Some demonstration of competency can be done in an SE, or one augmented by a physical device as described next, but typically students are assessed and their skills validated in a live environment, when available. The more realistic the setting in which skills are demonstrated, the more confidence both instructor and student will have in their successful application.

Part-Task Trainers

The gain-practice-demonstrate framework applies to training of social interaction skills—the bulk of our current work—but also to hands-on skills, particularly when SEs are augmented by physical training devices such as part-task trainers (PTTs). PTTs can be integral components of learning environments and useful adjuncts to SEs. It is easy to see how efficient and effective SEs can be for acquiring and practicing physical, even spatial, elements of a skill when PTTs are added. Though obviously applicable to the learning of physical and motor skills, PTTs can also be used for cognitive and strategic skills.

PTTs are usually limited-functionality, high-fidelity mockups of part or all of a live environment. For PTTs to be used effectively, it has long been established that training guidelines should map task action verbs to knowledge and skills being trained (Gagné, 1962). But it is reasonable to conceive of these devices not only as training environments in their own right but also as components within an SE, in which case they are more like appended devices. For instance, having a joystick or game controller integrated into an SE helps the student learn when such movement is necessary (Hubal, 2005) and helps to capture observations and reactions in a convenient manner (Hourani et al., 2011). Similarly, interacting with a life-sized VH projected into the room offers a level of immersion that makes rapid decision-making vital (Schaffer et al., 2013), in line with the tension felt by medical students engaging with standardized patients (Parsons et al., 2008; Parsons, 2011a; Pataki et al., 2012).

It is this latter example that hints at how PTTs can support learning of cognitive and strategic skills. Practice requires repeated performance in an environment that alters to reflect performance outcomes. In understanding when and how to apply knowledge, and in realizing gaps in knowledge that need to be filled for particular tasks, a student demonstrates strategic knowledge. In performing the skills under realistic conditions, a student experiences the breadth of content associated with the skill. For instance, deciding which of multiple paths to take to reach point B from point A requires application of a strategy. This observation is as true of a motor skill like driving (e.g., in a military vehicle, accounting for terrain, fortifications, and support systems) as it is for engaging in dialog with another individual (e.g., during the conversation, accounting for topics covered, topics to be avoided, and dyadic norms; Hubal et al., 2015b). That is, one strategically applies declarative or procedural knowledge (or both) and experiences consequences. The ability to demonstrate skills is enhanced in ever more realistic contexts such as those provided by PTTs.

Augmented and Mixed Systems

To this point we have purposefully avoided rigorously defining the "synthetic" in SE, because there are different means to present the environment, and we feel our ideas apply across them. Indeed, we have shown that, for many applications, relatively simple desktop simulation systems are satisfactory (Hubal, 2005, 2009). To be complete, though, here we outline some common intensive, more complex approaches for SEs.

In traditional virtual reality (VR), the individual is engaged in a fully immersive experience designed to instill a sense of presence. As an example, the VR environment may involve a head-mounted display (HMD) and data gloves that together present the full experience to the wearer. The HMD may have such features as a highly resolved camera, a depth sensor, tracking sensors via a 9-axis inertial measurement unit (IMU), and 3D audio. The depth sensor would be important for recognizing and segmenting body parts, particularly hands, during manipulations while the student demonstrates virtual hands-on skills. A good camera is important (in concert with the IMU) to accomplish closed-loop tracking of the student and environment. It may present the student with a 6-degree of freedom (DOF) view, "inside looking out" around a scene, or, depending on the task, an "outside looking in" configuration that represents 5-DOF.

Not all VR experiences, though, require these gadgets. For instance, several researchers have developed systems in which the student stands in front of a projected display and engages with objects and elements of the presented environment, with environmental trackers monitoring motion and interaction (e.g., Bowyer et al., 2008; Hays et al., 2012; Shapiro et al., 2015). Meanwhile, in augmented reality (AR) (Caudell & Mizell, 1992), the system overlays information onto the physical environment, perhaps, for example, via a pass-through camera, but does not otherwise interact with the physical environment. AR is based on geospatial locaters and other sensor data that act as fiducial markers for body positioning and visual overlays. A kind of combination of VR and AR is sometimes called mixed reality. In this environment, the system registers the real world digitally then overlays virtual content, and uses motion trackers and scanners for objects and boundaries to the current physical environment. This is technology with which one can bounce a virtual ball on a real table. Instead of fiduciary markers, mixed reality usually is focused on video, infrared signals, and depth capture of the scene. As such, it currently tends to track better on static objects.

The tools and techniques involved in VR, AR, and mixed reality—as well as other platforms for SEs such as the Web and even game consoles and smartphones—are advancing rapidly, blurring the lines of what is immersive and what is desktop. What required a large processor and bulky HMD some years ago that still resulted in jittery, time-delayed images now involves small, lightweight, fast mechanisms that yield ever-more-real depictions. While technological advancement enhances the effectiveness and versatility of mediated environments, researchers are also investigating how endogenous characteristics (personality traits, immersive tendencies, openness to experience) of individuals relate to the ways in which mediated environments are experienced (Parsons et al., 2015a). We do not know exactly where the technology will lead, but because they all are focused on increasing engagement of a user in a realistic experience, we are confident that the concepts associated with the SEs we have used will apply to future environments as well.

Student Control and Tutoring

Tutorial Roles

Good instructional technology that leads to experiential learning has the ability to support instructors and even replace some of their tutorial responsibilities. For an SE, as with any educational setting, it is important to address the amount of control given to the student, the scaffolding alluded to above. For instance, the amount of feedback, guidance, and tutoring to provide is roughly the inverse of student proficiency: too much for too long, and the student will have difficulty applying the knowledge; not enough, and learning will become inefficient. We think in terms of a VH tutor who may play any of a number of roles as the student progresses through lessons (Hubal, 2008b):

- Demonstrator. As the student is acquiring new knowledge or skills, the tutor can be most beneficial by demonstrating appropriate techniques and then virtually holding hands with the student to begin practice. The tutor demonstrates for the student best practices and good techniques, showing the sequence of steps of a task and what operations need to be done at each step.
- Trainer. Gradually, as the student gains proficiency, the tutor yields control. The tutor assists the student in progressing through learning material, providing content-relevant help. The student is largely in control of learning, though frequent assessments of knowledge can help keep learning on track.
- Coach. The tutor plays an active role in prompting or assisting the student through modules and exercises. For instance, the tutor can offer guidance in the form of suggested responses before each conversational turn in a mock interview and feedback after the turn. However, the student actually performs the steps of the task.
- Mentor. The tutor plays a less active role, offering help, remediation, or critique when necessary or when requested by the student. The tutor is available to answer questions posed by the student, and to interact with the student

via dialogs on specific steps of a process. While learning is proceeding, the SE is monitoring the student's actions to be able to provide context-sensitive assistance regarding the current state of the student's efforts. The tutor may intervene if the student makes a critical mistake.

- Observer. The tutor watches and records, noting the student's efforts at task performance but rarely interfering. After the task has been completed, the tutor conducts a dialog with the student about the student's efforts, and/or plays back portions of the interaction to the student so that the student may also observe and reflect on performance.

We are advocates for intelligent VH agents as tutors associated with an SE and their verbal dialogs. VH tutors can provide a more natural and realistic interface for training than pushing buttons to select video sequences or taking multiple-choice tests. VHs can step out of tutorial roles and into roles associated with the situation, such as a partner or observer, yet maintain awareness of the student's actions and intervene as or if needed. During skills acquisition and early practice, there may be no need for a second student to conduct the role play; in the second student's place, one or more VHs can play roles while a VH tutor simultaneously observes and records the interaction, and provides guidance and feedback when needed or requested. Observation and assessment become more robust but also easier to control when these roles are automated.

In the mentor role, the tutor is responsible for defining a structured training program for the student. This role involves two related efforts. First, the role demands selecting the appropriate sequence of situations for the student based on the student's background and history of performance during previous situations, known as outer-loop tailoring (Wray & Woods, 2013). Second, it means adjusting situational, context-specific parameters on the fly based on perceived student strengths and weaknesses to provide the most valuable learning experience, known as inner-loop tailoring.

Capture of Student Data

Interactive SEs provide opportunities to unobtrusively and continuously collect data on student behavior. Tutoring reports should provide guidance and feedback that students can use to adapt their practices within training and assessment sessions. The reports should be based on LOs required for performance success. A good tutor would have several key elements, including objective evidence of both expected and unexpected actions, processes for determining how and why the actions took place, and methods for determining how to repair what is unexpected or wrong and sustain what is expected or right.

LOs and performance measures are initially defined by an instructor or expert in terms of student actions that are detectable by the SE (Frank et al., 2004). For the tutor to issue Success and Non-Success assessments for an LO associated with a performance measure, there must be a log showing which particular student actions completed the requirements for a Success or triggered a Non-Success. These data help students determine why specific results were reported. We have identified several types of detectable patterns:

- Context errors occur when students perform actions that are not appropriate for the context (that is, the particular situation under which there are constraints on student activity).
- Errors of commission occur when students take actions that are to be avoided in the context. A student may receive a Non-Success but be allowed to continue to work the lesson.
- Errors of omission occur when students fail to complete required actions or sets of actions in a context.
- Dependency or sequencing errors occur when students perform context-appropriate actions in the wrong order (when there is a prescribed order).
- Timing violations occur when students exceed the time permitted for the task.
- System violations indicate mistakes by students so egregious that the lesson is immediately stopped. (These errors typically are associated with safety violations or indications of deviation so far from the required process that recovery is not possible in the test or assessment.)
- Impasses are points within the test or assessment where student actions indicate a mental hurdle to overcome, perhaps due to lack of knowledge or possibly due to misapplication of procedure.

Most of these types of errors can be assessed in SEs, by maintaining state variables to track students' activities (Hubal, 2008b), by calculating end-state measures (the final result of the test or assessment), by watching how and which production rules are triggered (Anderson & Corbett, 2014), or by applying data-driven methods (Koedinger et al., 2013).

A tutorial system could adapt to students based on their levels of learning, and present them with a variety of remediation or recommendation options (Frank et al., 2004). As examples, given the patterns identified (e.g., context errors vs. system violations) a tutor within an SE may encourage students to shift from a skill acquisition or practice mode lesson (focusing on procedural knowledge) to a lesson designed to obtain needed declarative knowledge; or it may back up, such as shifting from a practice lesson to an acquire lesson; or shift to analogous lessons (students having difficulty may shift from more realistic to more abstract lessons to reduce distraction, then transfer skills gained); or require repeating a practice or validate lesson resulting in a Non-Success, while helping students to determine where their errors occurred. The point is, additional information about students and their activities, along with links between actions and performance measures, enable the SE to better tailor and adapt its tutoring.

Development of Best Practices

These realizations can inform materials design and development. The designer should take into consideration the LOs, relevant situations to motivate students, available technology, and tutorial practices to create a desirable learning environment. Well-designed SE-based materials demonstrate many of these characteristics:

- They are modular. Different objects, characters and their behaviors, virtual worlds, multimedia, and other components can be inserted, combined, modified, or replaced to meet situation-specific LOs with minimal effect on other components.
- They are reusable. Effective reuse requires materials be developed with common standards. For example, a VH's behavior engine might employ social and emotional models that can be reused as training source material. Once constructed, these materials can be adapted and redeployed for different portrayed situations and conditions.
- They are reconfigurable. Each student has a unique set of learning needs. It benefits learning and student motivation when the environment, including materials, are tailored to the student. Within and across training modules, though, including in SEs, analogies, examples, and themes should remain as similar as possible.
- They are scalable. A key to reducing the cost of training materials is to enable materials to work across a variety of platforms, interaction techniques, and distribution methods. For example, an SE might be designed to work in a PC-based gaming environment but also accessible on a mobile device as an app or web-enabled service. A server sitting on the cloud can run the majority of an application, and, if the application is designed properly, only small changes and data need be sent to and from the client side, making distributed learning highly efficient over even small-bandwidth transmission systems.
- They are flexible. Practicing skills in a safe and supportive—virtual—environment allows the student to learn flexible approaches, meaning the student can learn multiple paths to success (thereby meeting LOs) and explore different techniques under different conditions. Flexibility is equally critical for hands-on interaction skills and for performing adequately under time- or resource-constrained, dangerous, information-poor, and other difficult conditions. The consistency that is gained by repeating this practice in SEs leads directly to good decisions in real situations. Practice also leads to increased confidence prior to the first real experience.
- They are self-contained. Open standards and open systems solutions present guidelines for the self-containment of reusable, reconfigurable training modules (Poltrack et al., 2012). Different situations portrayed by SEs should stand alone as presenting a unified set of LOs and performance measures, so that in

aggregate, across a sufficient range of situations, the student is able to acquire, practice, and demonstrate all of the relevant skills.

- They are cost-sensitive. The cost of developing SEs can be higher than the cost of developing, for example, lecture materials. However, costs associated with obtaining, maintaining, and retaining live systems far exceed costs associated with virtual acquisition and practice of skills on expensive, dangerous, or otherwise unavailable equipment. The cost of an SE—and especially the ability to fail safely in an SE—is much lower than in a live environment, so that as a whole the use of an SE for skills training may be cost-effective.

Presentation

Well-designed training SEs permit experiential learning on relevant material for a specific learner rather than following a hard-wired sequence of learning activities. The SE presents neither simple direct instruction nor complex high-end simulation, but instead pushes the student through a series of phases (Milrad et al., 2003). The first phase is presenting a real-life, applicable situation to motivate the student to explore the problem space. The second phase is to let the student attempt, and perhaps fail, at finding solutions; it is important to let the student create sub-problems and find mistakes in reasoning and perceived relationships, all in a low-risk environment. If successful, the student realizes a sense of disequilibrium that encourages a reconceptualization of the problem, pragmatically with feedback and guidance from a tutor. (There are many instructional concepts that underlie these ideas, chief among them the zone of proximal development that directs a learning system to constantly but carefully push the boundaries of what a student is capable [Vygotsky, 1978]). The third phase involves the student practicing and achieving proficiency in the SE in increasingly different situations (van Merriënboer et al., 2002). Iterations of this sustained exploration learning process lead to a cognitive flexibility that suits the student in analogous and, to some extent, unrelated situations.

To adapt the presentation of situations in an SE to support these three phases of the learning process requires technology to provide scaffolding and facilitation appropriate to each phase. Adaptation takes two forms, in presentation of information to the student, and to the individual requirements of the student.

The format in which a student encounters to-be-learned information affects how the student learns and what information the student gleans from it. Alternative representations research has shown that when identical information is displayed using different formats, resulting cognitive task performance varies (Day, 1988). For instance, charts and matrices provide dimensionally organized, indexed information but no sequential information. Graphs and pictures provide spatial cues and show visual patterns, but lack indexed cues into the material. Lists and outlines provide indices and sequential information but lack pattern and dimensionality. Generally, spatial visual representations assist performance more than non-spatial alternatives, on tasks including recall, comprehension, and motor skills. However, alternative representations differ in format used, and therefore differ in applicability to specific cognitive tasks, and affect acquisition of information. No one representation is necessarily superior to another; rather, the situation informs a good selection of format.

SEs use dynamic tailoring (Wray & Woods, 2013) to adapt and present instructional materials to the student. For instance, in a military setting, different representations are required at different echelons of command. Whereas a battalion commander needs to understand at an aggregate level such battlefield factors as terrain, logistics, readiness, and enemy information, a company commander needs much more specific and localized knowledge of those factors. As the LOs are defined differently so should the form of presentation change—from the symbols used to level of simulation of virtual entities (e.g., individuals vs. organizations).

Presentation is not solely display format. When it makes sense, an SE should support different students' desire for visual, auditory, haptic, spatial, or kinesthetic feedback and guidance. For instance, a tutor might use highlighting, voiceover, vibration, forced change in perspective, or some other mechanism to draw attention to a critical entity or aspect of the situation to the student (Frank et al., 2004). The same is true of the toolset provided to manipulate entities in the SE. For instance, there may be multiple methods to navigate the portrayed scene and manipulate objects (Hubal, 2005).

Historically, few systems have been adaptive to individuals considered as people with habits, interests, moods, and prior experience; few systems have dynamically changed the selection of the input materials, the nature of the interface, the construction of learning activities, or the tutoring based on a holistic profile of the student's preferences, prior experiences, and past performance. However, many current systems are using adaptive strategies by modeling the user's performance and behaviors (Brown & Guinn, 2014; Steichen et al., 2013; Woolf et al., 2009). Developers can use these models for incorporating student-specific information profiles. SE systems with this level of flexibility will optimize their potential.

Fidelity

SEs share many attributes with computer games and typically are built on top of game engines. Game designers have a broad view of fidelity that applies to SEs for training and assessment, in effect aiming to trigger willing suspension of disbelief on the part of the student using computationally efficient methods (typically maintaining a frame rate of 60 frames per second for most platforms). We and many others have explored different forms of fidelity (Parsons et al., 2012); what is discussed next has focused primarily on the virtual humans involved in simulations, though the concepts apply rather well to virtual objects, environments, and other aspects of the SE.

VHs can be simulated with variable degrees of fidelity, in this case, the degree to which they resemble people. Though there are no universal opinions about the nature, feasibility, and desirability of VH fidelity (Prendinger & Ishizuka, 2004), we have identified over a half-dozen types.

Appearance fidelity, the degree to which a VH looks or, in some cases, sounds, like a real human being, is important but potentially subject to the situation known as the uncanny valley, in which increasing realism eventually creates unrealistic expectations for the VH to exhibit intelligence (e.g., Burleigh et al., 2013; Reeves & Nass, 1996). By contrast, some developers rely on the power of artful low-fidelity animation to create strong user engagement with the VHs (Dukes et al., 2013; Lester et al., 1999).

VHs also have important dimensions of psychological fidelity, which may be an equally or more important factor in training efficacy. One dimension is the ability to improvise or exhibit a range of human-like intelligence (Hayes-Roth, 2004; Skorupski et al., 2012). Another dimension is ability to interact naturally, as with mixed-initiative natural language conversation, including degree of politeness, personalization, and tailoring of linguistic complexity (Hayes-Roth et al., 2009; Hubal et al., 2003b), and with appropriate gestures and overt behaviors (Cassell et al., 1999; Lhommet & Marsella, 2013). Yet another dimension is emotional realism exhibited by the VH during the interaction (Ferreira et al., 2012; Gratch & Marsella, 2001; Hubal et al., 2003b). Still another is comprehension of social and cultural roles and the degree to which VH behavior reflects and reinforces the relative social status as displayed during the interaction with the student (Hubal et al., 2008; Kistler et al., 2012; Maldonado & Hayes-Roth, 2003).

Levels of Interactivity

Given our suggestion that SEs can be supported by numerous platforms—from desktop PCs to mobile devices to VR and AR systems—it makes sense that there are different types of interaction with and within SEs. There is no one best path; the designer needs to consider how students will engage with the SE in what settings, and support those forms of engagement, but also allow for flexibility when possible. To be specific, a PC-based SE naturally lends itself mainly to traditional input mechanisms such as keyboards, mice, and game controllers, but also offers a high-resolution output display and high-quality sound. Immersion in the system comes from students focusing on the video and audio to the exclusion of the outside world, a state that game developers have long sought. The display and sound allow for some flexibility in what is presented to the student, such as scoring updates, ready links to help content, and alternative methods for the student to accomplish tasks. In contrast, a smartphone, even today's bigger ones, has a limited screen and very different input methods, from touch and swipe to shaking to voice input. It is part of the outside world, and as such might be incorporated more closely into the live environment. Meanwhile, donning an HMD separates the student from the world, in a sense, and encourages realistic activity within the confines of the situation that is presented. The same content may be contained in all versions of the SE, but the means of interaction and the modes of usage are necessarily different.

Measurement

Measurement in SEs involves a continuous data collection process aimed at understanding and improving student learning. It involves setting LOs, systematically gathering, analyzing, and interpreting evidence—including suggestive patterns such as errors of omission or commission—to determine how well performance meets those objectives, and using results to inform the tutorial process. Measurement at the front-end of training should identify and link measurable goals with critical accomplishments or best practices. These links will allow for later impact evaluation (described below) when the student attempts to use learned knowledge and skills.

A traditional measure of acceptable training held that students would be able to demonstrate their skills under certain conditions to set standards (Frank et al., 2007). This concept has evolved to an extent recently and a newer focus is now on outcomes—do students end up thinking and behaving adaptively to the situation presented (Riccio et al., 2010)? The use of SEs underlies some of this change of tack, since they allow students to explore better and worse paths and encourage reflection. Relatedly, the measure of educational productivity traditionally was schoolhouse-centric and mainly considered the effective use of instructor hours, classroom space, and other resources. The use of SEs strongly influences how productivity is measured, though. For example, SEs, along with other learning technologies, can increase student-to-teacher ratios and support asynchronous remote learning. Hence, the return on investment promised by SEs needs to take into account the cost shift from providing set instruction to delivering reusable, reconfigurable instructional materials.

Evaluation and Assessment Strategies

We use the terms assessment and evaluation carefully. In any learning context, students are assessed—formatively, to support improvement, and in a summative manner, to indicate level of mastery or understanding at the end of a training module. The learning context itself, though, is evaluated—formatively, to help instructional designers achieve intended goals and objectives, and in a summative manner, so as to be able to report the extent to which goals and objectives were attained. Evaluations often include student assessments, but also typically go beyond those assessments to include other factors such as cost, support requirements, and long-term benefits.

To obtain suitable measures of student learning and training cost-effectiveness, there is a need for evaluation at multiple levels. Here, five are described (adapted from Kirkpatrick & Kirkpatrick, 2005).

At Level I, reactions to the quality of training delivery itself are obtained. Training developers and instructors use these reactions as feedback on their efforts. Effective training is rated as specific, reliable, representative, and objective. We have consistently found SE-based training applications, when designed intelligently, to meet Level I criteria, meaning they are accepted by students who find them engaging. Gauging reactions is often done using surveys and observation of learning as it occurs, which can be built into the SE, but user sensing while the student is engaged in the SE and detailed analyses of actions taken within the SE can also inform reactions.

At Level II, actual learning by the student is measured. At this level, assessment comprises testing of knowledge and validation of (i.e., demonstrating of, in a cross-section of representative situations) skills. Students and instructors care most about results at this level. Given their ability to collect and analyze large amounts of performance data from students and use tutorial strategies to remediate or recommend next lessons, SEs are well-positioned for meeting Level II criteria.

At Level III, assessment is of the success or failure of transfer of knowledge and/or skills—the impact of training on real-world performance. Similar measures are used as at Level II, but under uncontrolled, out-of-routine, or analogous conditions rather than controlled, structured, already-encountered testing conditions, thus addressing outcomes-based testing and evaluation. Transfer is promoted by several principles for which SEs are helpful, including deliberate practice, distributed practice, variability of situations, and explicit outcome feedback (Hoffman et al., 2014). Instructors use performance measures to evaluate the value of training and the need for additional or restructured training, as well as sustainment of training as skills decay. For the same reasons as Level II, SEs are useful for satisfying Level III criteria.

At Level IV, organizational improvement as a result of training is evaluated. Management is concerned with whether or not skills are being applied effectively, whether those who are trained are more productive and efficient, and whether strategic missions, values, and goals are met. At Level V, societal impact is evaluated. Issues such as readiness and morale, ability to work with others (both inside and outside the organization), and perception of competence are important to strategists and decision-makers. For these levels, though SEs can support training, the measures are somewhat beyond scope.

Assessment Strategies

Assessment is the measure of LOs and skill competencies before, during, and after training. Performance is measured against set criteria, with outcomes in mind; therefore results focus training on what students need to know and when and where they need to know it, and provide links to prescriptive training. Assessment, including that done in an SE, can be used as a placement test, allowing for testing out of lessons, modules, or phases of training.

Performance Tests

A simple performance assessment, of course, has little to do with the SE. Instead, it is a means by which the student describes what processes would need to be performed, in what order, for a particular task, duty, or skill. These simple tests are useful for determining whether or not students have declarative knowledge of the skill, that is, they help us know whether the student understands and is able to state the requirements of the skill. These tests may also be useful for determining whether or not students have strategic knowledge, that is, if they understand the contexts and conditions in which the task or duty is to be performed or skill is to be demonstrated. If the questions are constructed well, errors that the students make will indicate areas in need of remediation.

A more complex performance assessment is usually needed, however, for students to actually demonstrate, not just describe, skills (Hubal, 2012). These tests are complex in part because they can be resource-intensive; an SE (perhaps with PTT), though a viable means to assess skills, must be developed and delivered. However, there are many reasons to view SE-based assessment as cost-effective. First, they are useful for determining whether or not students have procedural knowledge of the skill. Second, they are useful in that skills demonstrated in a range of situations portrayed by an SE typically transfer directly to real-world conditions. Third, the assessment can be integrated into the learning environment, making the transition back and forth between training and assessment seamless while keeping students engaged. Fourth, for SEs, the learning/assessment environment is portable to remote locations and to off-hour learning times, so that students can learn, test, re-learn, practice, and sustain training using distributed learning at their own schedules. Fifth, students who fail to be engaged in the standard knowledge learning such as takes place in a classroom will often become immersed in SEs. Sixth, because students demonstrate procedural knowledge, achievements that they show lead to directed forward recommendations while errors that they make directly indicate areas in need of remediation.

For many skills, students may need to understand the LO requirements and constraints, but they may not need to have achieved mastery of the skills. Assessment should reflect the need for each student, be it familiarity, competence, or mastery. More specifically, there may not be a need to validate students on all skills. Instead, there may be a need to validate students on some skills, have them practice to a lesser degree other skills, and let them become familiarized with still other skills. For instance, if a set of relatively non-critical tasks requires comparable skills, then performance on only a small subset of those tasks may need to be validated. For the remaining set, familiarization and acquisition should prove sufficient, so that the skills will successfully be applied to them. The identification up front of analogous skills is important for realizing cost-effectiveness from the use of SEs as part of the learning environment.

Links to Recommendation and Remediation

Feedback from knowledge test results, whether simple multiple-choice tests or complex adaptive tests, is used to link to training in specific areas that need to be remedied. Feedback from performance test results, such as are captured through SEs, is also used to link to training in specific areas that need to be remedied. The feedback is useful if two conditions are met. First, the tests themselves must be well constructed, for instance by using validated test items or well-defined LOs and outcome measures, so that a correct response can be assured of indicating areas of strength and an incorrect response those of weakness. Second, the training must be designed in modular fashion, so that remediation of specific learning areas can occur, without the need for the student to re-encounter areas that do not need to be remedied. The process is then iterative; students need complete only appropriate sections of the assessments.

In past work we have set out some rules for remediation and forward recommendation. For instance, if the student achieves an overall Success on a practice lesson, then consider what gains the student could make from either portraying a more complicated situation (using, as a framework for determining complexity, an LO hierarchy or a student model derived from a dynamic tailoring system) or by presenting new content to acquire. In contrast, if the student achieves an overall Non-Success, then consider re-introducing content to be gained or simplifying the situation.

Efficiency and Measuring Effectiveness

There are often effectiveness requirements of training. Students are expected to learn quickly, remember content over time, and apply their learning to analogous situations. To be effective, SE materials must emulate effective instructors and establish a motivating environment in which to learn. There are often efficiency requirements of training as well. There may be a need to put a certain number of students through training in a given period of time, a limit on organizational training dollars, or a limit on training time and associated costs. Additionally, there may be a need to distribute training and a consequent initiative to implement intelligent tutoring into the training environment.

Throughput, for instance, is traditionally limited by the availability of instructors and facilities and the real-life situations needed to validate skills. SEs are not live environments, and thus present some restrictions on how transferable successful demonstration of skills is to real-life situations, but they can be used to minimize the time needed within a live environment (Frank et al., 2000).

Further, by incorporating a PTT into the SE, trainers allow the practicing of hands-on skills, individualized tutoring with situations tailored to the given student, and, for high-fidelity trainers, validation of some skills. SEs, with facilitating intelligent VH agents, allow tutoring to take place as needed. SEs can also be used to train more students with fewer resources, as they can be designed for distributed usage at times most convenient to the students. Students can progress at their own pace, acquiring skills when they are prepared to do so and moving to practice facilities at staggered times. This staggering naturally increases throughput at no expense to learning. By obviating some live assessment and even minimizing travel expenditures to a schoolhouse or practice facility, SEs can reduce training costs. SEs are also available for sustainment training to address skills decay.

Skills Decay

The ability to perform a skill decays at different rates depending on the form and intensity of initial learning, ongoing use, and periodic sustainment training. A number of factors influence decay, including passage of time, lack of practice or repetition, fatigue, and situational characteristics (e.g., cognitive vs. hands-on tasks) (Hoffman et al., 2014). In general, SEs provide the opportunity to overcome decay. For instance, SEs allow for spacing of learning and presentation of a variety of situations, to avoid repetition over successive trials but also because one of the main determiners of successful performance after a delay is the similarity of conditions to those of the training. The skill can be practiced in an SE, with different virtual conditions easily inserted to adjust for individual student needs and application to analogous situations. Skills that are applied to increasingly different situations will generally be less prone to decay than those not applied at all or those not applied to contexts outside of the learning context. The student is able to form a more complex mental model of how the skill is to be performed, which in turn gets strengthened with each new application. In contrast, a student who applies a skill in only one context will become expert in a very narrow domain. SEs are easier and less costly to adapt than live equipment.

Spaced practice means that attempts at relearning occur at somewhat regular intervals, with each relearning session being short and goal-directed. Once knowledge is acquired or skills gained, spaced practice leads to better retention than brief, extremely intense bursts of relearning. An example session would consist of first rehearsal of the skill in a context similar to the original learning context, and then application of the skill under different contexts. In contrast, an example of a cramming session would be one where the skill must be applied immediately to an unfamiliar situation, requiring a stressful attempt at relearning without being allowed to rehearse what is remembered first. Relatedly, knowledge and skills are recalled best in an environment closest to the one originally learned. This does not contradict the requirement for generating a range of situations, but instead suggests that if the student is expected to master a skill, rather than become familiar or proficient with it, then initial training and later practice must become more intense. The more realistic the practice and validation settings, and the more able the student is to recreate that setting during sustainment training, the better performance will be, and the slower the skills decay.

At least three interrelated factors contribute to the decision of how frequently and how intensively to conduct sustainment training. The first factor is importance or criticality of the skill to be maintained. For critical skills, sustainment will generally require less intense training more frequently, whereas for less important items, sustainment will often require more intense training less frequently. The second factor is pre-established validation requirements. Some skills will require frequent validation (either because they are critical or because they are commonly needed), others only occasional. The third factor is intensity of retraining (i.e., amount of re-acquisition, practice, and validation needed). Less intensive sustainment training is required when students are already familiar with the skills and will likely be able to perform them. More intensive training is required when the skill is critical, difficult, or time-consuming, considerable time has elapsed since the original training, or the original program of instruction did not include intensive training for that skill. In all cases, SEs can be useful to support sustainment training of skills.

Example Applications

In this section we present some examples of our work with SEs for training and assessment. What is described is not only just an illustration of our work but also a small sample of the entirety of simulation systems used in medical, military, and education domains.

Virtual Human Patients for Training and Assessment

We have been engaged with research and development in two broad medical-related areas, healthcare provider training and decision support. Both areas use SEs, on the one hand to present an environment for students to acquire and practice basic skills and on the other hand for better acquiring health-related information.

In the first case, VH agents are used to create clinically relevant VH patients to apply to the training of clinicians, medical students, first responders, and other healthcare staff. VHs portray a patient with a clinical, medical, or physical condition and can interact with a healthcare provider in an effort to teach emergency response or interpersonal skills, or focus more on differential diagnosis and therapeutic intervention. The work reflects lessons learned over many years of research and development (Hubal et al., 2000, 2008; Parsons et al., 2008, 2009b).

SE technology has evolved to a point where there are now many applications that make use of VH patients. Figure 11.3 shows a few some readily accessible images from these SEs. Some applications include:

- Virtual standardized patients. The medical training world uses standardized patients (SPs)—specially trained actors who present as patients—for the acquisition, practice, and assessment of skills related to the physical examination, doctor–patient interaction, and diagnostic decision-making. Early on Hubal and colleagues realized VHs could be used as SPs for specialized skills (Hubal et al., 2000), including as patients who present with rare but serious cases such as exposure to bioterrorist agents (Kizakevich et al., 2003) as well as pediatric patients for whom it is very difficult to hire consistent, reliable actors (Hubal et al., 2003 Parsons et al., 2009). Parsons has used VHs as SPs for investigating training on topics such as structured interview procedures (Parsons et al., 2008), assessing bias (Parsons et al., 2009b), and post-traumatic stress disorder (Kenny et al., 2008).
- VHs for emergency response. First response to medical events is a combination of physical and cognitive skills. Hubal and colleagues have long been involved in developing SEs for emergency medical response training and assessment, beginning with the strategies needed for uncommon but critical

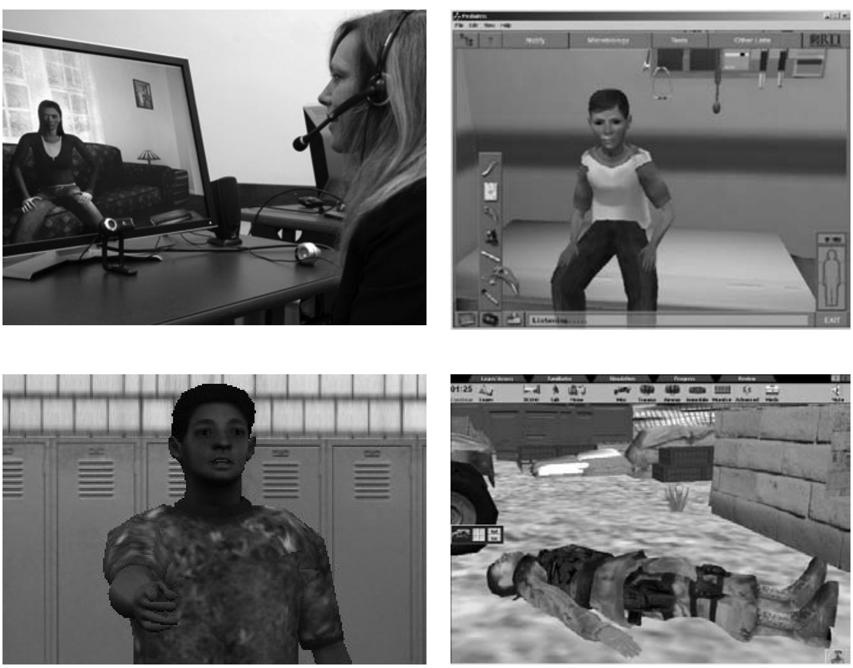

FIGURE 11.3 Virtual humans as patients and peers

trauma conditions like gunshot wounds and worksite explosions (Kizakevich et al., 1998) and progressing to specific procedures to follow in triage situations (Kizakevich et al., 2007). Others (e.g., Goolsby et al., 2014; Hsu et al., 2013) have investigated SE use for disaster preparedness and hands-on components of SEs for emergency response.

- SEs for clinical applications. Numerous studies, many conducted by Parsons, indicate that SEs are applicable to patients with neurodevelopmental or psychological disorders (Parsons et al., 2009). For instance, they may be especially enjoyable and motivating intervention platforms for persons with high functioning autism (Parsons & Mitchell, 2002). As they interact in virtual social situations, the consequences of patients' actions (positive or negative) can be carefully controlled by the clinician, the realism of social interactions can be varied, and the pace and complexity of exposure to social contexts controlled. The types of safe role-playing available in virtual social encounters may be especially vital as well for other neurodevelopmental disorders. For instance, SEs have been used during exposure therapy to emotionally engage anxious or phobic patients (e.g., with post-traumatic stress disorder) using gradual, controlled sensory stimuli (Parsons, 2015b; Parsons & Rizzo, 2008a).

In the second case, SEs and VH agents are used to augment a healthcare provider's ability to capture relevant or diagnostically important information from the patient. The SE presents a situation and the patient responds appropriately; data are then interpreted, summarized, and returned to the provider. Some applications include:

- Measures of social information processing (SIP). We have both—separately—developed systems for assessing SIP skills. Hubal developed an SE to help identify the underlying neurocognitive and emotional regulatory mechanisms in behavioral disorders that at-risk teens often present and to understand how these mechanisms influence treatment outcomes (Hubal et al., 2008; Paschall et al., 2005). Other colleagues have developed an SE focused on autistic-spectrum preteens (Russo-Ponsaran et al., 2015). These systems are an improvement over existing measures of social skill, given their standardized, SE-delivered form that reduces scoring time and increases comparability across populations, and their reliance on theory to pinpoint specific SIP deficits to guide intervention.
- Obtaining cognitive measures. Parsons has conducted a series of studies using SEs that focus on component cognitive processes, under the presumption that more engaging, ecologically valid environments will elicit better measures (Parsons, 2011b, 2015a; Parsons et al., 2015b; see also Hubal, 2012). The processes addressed include attention (Parsons et al., 2007; Parsons & Carlew, 2016), workload (Parsons et al., 2009a), spatial abilities (Parsons et al., 2004, 2013b), memory (Courtney et al., 2013; Parsons & Rizzo, 2008b), affective

processing (Macedonio et al., 2007; Wu et al., 2010a, 2010b, 2013), and executive functioning (Parsons et al., 2013a; Parsons & Courtney, 2014; Parsons & Carlew, 2016).

- VHs as neuropsychologists. We are currently engaged in a collaborative study to design, prototype, and test an SE that can be used by a clinician to administer neurocognitive assessments. The tool is intended to have a VH administer verbally based neuropsychological tasks including word-list learning, confrontation naming, and aural comprehension to the patient through a collaborative engagement that will yield data that are at least as comprehensive and accurate as those generated through patient interactions with a real clinician.

SEs for Warfare, Security, and Policing Environments

We make no attempt, in this section, to cover in any detail the extraordinarily large range of SEs used for military training and assessment. Instead, we outline five areas to give a taste of their use, most of which stress cognitive over physical skills. Figure 11.4 depicts some readily accessible images from these SEs.

- SEs for maintenance training. One area is the development of a line of virtual trainers for maintenance of United States Army ground tracked vehicles (Hubal, 2005). These SEs were mainly for hands-on skills training and were geared toward maintenance technicians and their need to learn to troubleshoot malfunctions in ground tracked vehicles. The SEs covered a number of vehicle variants and upgrades to equipment on the vehicles. Two conclusions, among

FIGURE 11.4 SEs portraying military and law enforcement operations

the many lessons learned from the development of these SEs, are particularly instructive (Hubal, 2009). First, the means of interaction within the SE should be flexible and to an extent customizable, so that students can choose from multiple modes to accomplish a task. Interaction includes navigation within the SE, manipulation of virtual objects using virtual tools, and communication with VHs. Second, the usefulness of an SE for maintenance training is tied closely with the entire training package, as is described above under the gain-practice-validate model. The acquisition of knowledge and basic procedures is cost-effectively accomplished in an SE, while for the practice and validation of skills a PTT and a realistic live environment are necessary.

- SEs for small unit training. Another area is SEs for practice of interactions with teammates, adversaries, and other noncombatants. VHs can provide features such as goal-directed, dynamic decision-making, non-determinism, and transparency (Stensrud et al., 2012). Under several projects a suite of VHs were created to engage students who were acting as squad leaders in small-unit training scenarios, including an intelligent enemy sniper capable of detecting and selecting friendly targets of opportunity, communicating with other insurgent support entities such as lookouts, and finding the appropriate escape path to avoid detection and capture; a fire team following the student; and noncombatant characters who engaged in normal patterns of life (Hubal et al., 2015a).
- SEs for stress training and therapy. A recent project focused on providing training to military personnel at risk for negative mental health outcomes due to combat and operational stress (Hourani et al., 2011). This training program was intended to prepare personnel for deployment by exposing them to a stressful environment (Hubal et al., 2010a), while simultaneously teaching coping skills and strategies that promote resiliency to stress. The program was designed to expose personnel to a simulated combat environment. This SE required personnel to manipulate joystick controllers in response to stimuli such as weapons, aircraft, and in general objects or events of potential concern (at their discretion) among snipers, explosions, flashes, objects, activities, and people. A separate project (Buckwalter et al., 2012; Rizzo et al., 2012); created a set of combat simulations as part of a multi-episode narrative experience. Personnel were immersed within "experiential" combat situations and interacted with VHs. The aim was to increase personnel thresholds for combat stressors.
- SEs for vigilance. Some homeland security operations require vigilance to potentially subtle events in the environment. An SE of airport security screening was developed to test issues such as detection of different classes of events (e.g., the presence of a gun in a bag vs. a particular individual entering a security line), individually or simultaneously, with varying time pressure, divided attention, and distraction (Hubal et al., 2010b). This work has been extended (e.g., Biggs et al., 2013) and is being used

to inform training of security personnel. Meanwhile, an SE-based cognitive performance assessment (Parsons et al., 2009a; Parsons, 2015a; Parsons et al., 2015b) is able to manipulate attention performance by varying stimulus complexity and intensity.

- SEs for managing explosive encounters. A final area involves SEs created to mimic difficult situations or those that might escalate into violence. One early example was an SE used for law enforcement officers to learn to manage encounters with the mentally ill (Frank et al., 2002). The student needed to learn appropriate verbal techniques to calm an angry and possibly psychotic VH. A more recent example involved "good stranger" skills that a deployed warfighter could use to manage the interaction with a foreign civilian sharing neither language nor culture (Hubal et al., 2015b).

Virtual School Hallways, Classrooms, and Street Scenes

Much of the previous work using SEs for assessment that focused on component cognitive processes were implemented into educational settings, with the purpose of teaching students (and assessing their progress) on very specific skills. Their effectiveness was made apparent through comparing the students' competencies within the area the SE was intended to teach before and after the students had been exposed to it. The SE used for much of this research, a virtual classroom (Parsons et al., 2007; Parsons, 2014), delivers a variety of continuous-performance tasks and attention-related tests in an ecologically valid, immersive setting. In other efforts students were presented with situations relevant to their backgrounds (e.g., inner-city male teens vs. suburban preteens) to assess their tendency towards risky behavior (Hubal et al., 2008; Russo-Ponsaran et al., 2015). In still other applications students were presented with street-level situations to gauge their ability to apply interaction and strategic skills to attend to multiple casualties or de-escalate a potentially explosive situation (Frank et al., 2002; Kizakevich et al., 2007). Figure 11.5 presents some images of these SEs.

Discussion

In this chapter we presented a number of considerations for education practitioners interested in using SEs for training and practice. Though we have been working with SEs for many years, and across many domains, the approach is still in its early stages, for at least two reasons. First, the technology upon which SEs are based is rapidly evolving. Our experience has largely been with PC-based SEs but, like many other researchers, we are moving to smaller, more mobile platforms with embedded sensors that were once less available and capable. These platforms and sensors present new affordances, and it will be important to determine how best to utilize them while adapting past processes and techniques. Second, SEs are not nearly so heavily used in education as they are in the military or medical fields

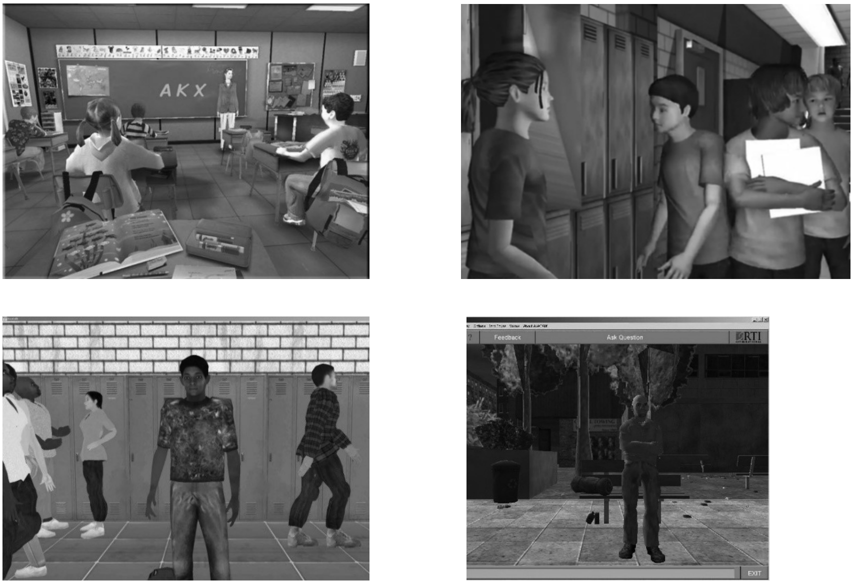

FIGURE 11.5 Virtual hallways, classroom, and street scene

for training and assessment. Though many researchers are developing interesting, novel, important applications, we believe the systematic approach we have taken to date will be critical to ensuring these applications are designed, developed, implemented, and measured appropriately to address future educational needs.

Impacts of Mobile and Wearable Technologies

As mobile and wearable devices decrease in size and cost, their usage for training and assessment will surely expand. Here we speculate how SEs might evolve as these emerging technologies become more capable and more commonplace.

One possibility is for tutoring to become tightly integrated into the use of the technology. Siri and Cortana are today's intelligent personal assistants with pedigrees stretching back to Apple's visionary 1987 knowledge navigator video, itself based on seminal artificial intelligence research (see Kay, 2013). They capture voice for basic speech recognition and can use built-in cameras to sense where the student is looking (Rozado et al., 2015). What they do not yet have, though, is an understanding of a particular student's needs, an ability to adapt to those needs, and a mechanism to track how that student has progressed through past training. We foresee the personalized assistants integrating components of dynamic tailoring and, through that enhancement, being able to better guide and provide feedback to students.

Another possibility is for location services to couple with the learning environment. Smartphones and -watches can capture GPS coordinates and potentially use other available sensors (e.g., gyroscope, accelerometer, or magnetometer) to gauge the student's physical movements; combined with augmented systems these data may be extremely valuable in tracking performance, as with PTTs or even stance and gestures during interactions. We envision sensing in SEs, indeed, to go beyond location into emotion and physiological state. For instance, components such as heart rate sensors or wireless heart rate variability monitors may be of interest for allowing the system to adapt to the student's current state, perhaps tailoring the learning experience to make it less or more difficult. A tool may adapt to the student based on some set of captured characteristics, including gender, age, vocal patterns, handedness (Wimmer & Boring, 2009), and gait (Iso & Yamazaki, 2006). So might near-future capabilities, from gauging emotional expression to assessing vocal affect (Sadat et al., 2014; Yang & Samuel, 2011), be used to influence what guidance and feedback is presented to the student and how it is portrayed. Even monitors of ambient temperature or environmental conditions could prove of interest to some training SEs, especially where they reflect realistic conditions of the live environment in which skills are applied.

A key to engaging the student on a mobile or wearable device is to enable "smart interaction," a means that is natural and intuitive to the student. It must be able to accept natural inputs across a variety of modalities and use those same natural modalities to communicate back. For example, speech is normal in most domains, and sketch overlays are often used when showing graphs, maps, diagrams, and other representational guides. We have conducted a number of studies using smart interaction to assist users in performing complicated tasks (Hubal et al., 2000; Guinn et al., 2004; Taylor et al., 2015). Smart interactive applications, as we view them, act as facilitators between the student and the system, interpreting student inputs in natural modes, translating these into commands to make sense of the environment, and then conversely translating sensed data from the environment into useful, relevant information for the student (Taylor et al., 2012).

Integration into the Science of Learning

In a comprehensive look at the state of the knowledge of how people learn (Bransford et al., 2000), a National Research Council (NRC) committee advocated for structured learning experiences, for taking into account cultural and social norms in how and where people learn, for the need for judicious guidance and feedback, and for taking continual advantage of the affordances of emerging technologies. The book was very influential when it was published almost two decades ago, and a new NRC committee is at present studying subsequent research that focuses on the study of learning in both formal and informal settings. We, then, are certainly not alone in practicing a systematic approach to learning. Nor are we unique in our promotion of synthetic learning environments. Researchers are studying how best to represent concepts in simulations, and help students establish relationships—both formally defined and intuitive patterns—among concepts. We are coming to see how and when different types of SEs can exploit a student's perceptual, spatial, verbal, and even kinesthetic abilities in environments that declarative or static presentations cannot. Because SEs simulate any situation, they can be valuable for dangerous, costly, rare, and even "impossible" (in the real world) situations, allowing students to explore, inquire, and interact as they desire. Cannon-Bowers and Bowers (2008), for instance, describe how simulations, virtual worlds, and games overlap but are all able to portray some sort of learning experience. They also present design considerations for SEs for learning much in line with many of our recommendations. Salas and colleagues (2012) argue for a "psychological" fidelity (i.e., the level of realism needed for gaining knowledge and acquiring skills to accomplish a task) in SE design, with the requisite measurement and tutoring. These and many other studies are showing why SEs work for training and assessment.

Summary

In this chapter we present a number of considerations for education practitioners interested in using synthetic environments for training and practice. Under development of these training environments we discuss learning objectives, the gain-practice-demonstrate model, part-task trainers, emerging technologies, and tutoring, and provide best practices. For presentation of SEs, we examine fidelity and levels of interactivity, leading to a discussion of measurement and its effectiveness and efficiency. We provide a host of examples from our work and others' to illustrate the many forms SEs for training and assessment can take and domains towhich they have been applied. We see the content in this chapter as a framework to guide practitioners in their decisions of why and how to undertake their own SEs.

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