Sorting Out the Virtual Patient:
How to Exploit Artificial Intelligence, Game Technology and Sound Educational Practices to Create Engaging Role-Playing Simulations

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ABSTRACT

Since Dr. Howard Barrows (1964) introduced the human standardized patient in 1963, there have been attempts to game a computer-based simulacrum of a patient encounter; the first being a heart attack simulation using the online PLATO system (Bitzer, 1966). With the now ubiquitous use of computers in medicine, interest and effort have expended in the area of Virtual Patients (VPs). One problem in trying to understand VPs is that there are several quite distinct educational approaches that are all called a 'virtual patient.' This article is not a general review of virtual patients as current reviews of excellent quality exist (Poulton & Balasubramaniam, 2011; Cook & Triola, 2009). Also, research that demonstrates the efficacy of virtual patients is ample (Triola, et al., 2006). This article assesses the different kinds of things the authors call "virtual patients", which are often mutually exclusive approaches, then analyzes their interaction structure or 'game-play', and considers the best use scenarios for that design strategy. This article also explores dialogue-based conversational agents as virtual patients and the technology approaches to creating them. Finally, the authors offer a theoretical approach that synthesizes several educational approaches over the course of a medical encounter and recommend the optimal technology for the type of encounter desired.

Keywords: *Medical Education, Medical Games, Medical Simulation, Serious Games, Virtual Patient, Virtual Standardized Patient*

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A WHIRLWIND TOUR OF VIRTUAL PATIENTS

As previously stated, many different entities with unique approaches and attributes are all often called virtual patients. Such approaches include case presentations, interactive patient scenarios, virtual patient games, human standardized patients, high fidelity software simulations, high fidelity manikins and virtual human conversational agents. Salient features of these virtual patient approaches are summarized in Table 1.

The Case Presentation

Case Presentations are a staple of medical education and are widely employed in both multimedia and print. They consist of a paragraph of text that summarizes a patient presentation and findings followed by a series of multiple-choice questions (Figure 1). They are often employed to test or reinforce basic medical knowledge regarding a specific type of case and are also used to evaluate clinical reasoning. Case presentations may not even be interactive, but may simply record learner responses for testing purposes. With multimedia case presentations, some at least try to provide feedback regarding the learner's choice of responses (Talbot, 1997). This level of interaction is fairly limited and really can't be considered as game play. Some online and multimedia versions of case presentations have been labeled as virtual patients simply because they are presented on a computer. These flat constructs test core medical knowledge and clinical reasoning skills. They can be useful educational adjuncts for teaching knowledge items and clinical reasoning if they are built in a way that offers some type of useful feedback. Providing scores that tally correct and incorrect responses, a typical approach, may be worthwhile for assessment but they are not useful for didactic purposes because numeric scores contain no educational content. The primary reason for the ubiquity of case presentations is that they are very easy to author. They can be written by a typical medical educator who need only provide a medical history, several questions and hopefully useful responses to user input.

Interactive Patient Scenarios

Interactive patient scenarios (IPSs) represent a very common form of virtual patient. When the term "Virtual Patient" is employed, this is the type of learning tool typically referred to. Interactive patient scenarios, which are usually text-based multimedia, build upon the case presentation with a few novel features; they may advance the progress of the patient over time, they employ substantial multimedia and they may have a branching structure that allows for considerable variation of the encounter experience.

Interactive patient scenarios are typically generated online and contain considerable multimedia in the form of photographs of patient findings, radiographs and auscultation sounds. The case history and progression may be presented through text or voice narration. They may advance a case to show ongoing symptom progression or response to treatment. If the interactive scenario does not allow the user to control the patient, it is called a linear case scenario. If it alters the progress of the case based upon the learner's decisions (typically multiple choice), it is called a branching scenario. Branching scenarios allow for considerably different patient outcomes based upon learner choices and they permit a richer experience. The main drawback to branching scenarios is complexity and effort to author them. Each branch represents a potential geometric increase in authoring effort unless the branching is tied back to one or a few linear narratives. Branching IPSs are often employed for teaching clinical reasoning skills and will often include both the diagnostic phase (interview, physical exam & test data) as well as the treatment phase of the patient encounter.

Branching interactive scenarios provide a good deal of game-play if the author creates interesting, mutually exclusive choices to the learner. They also can be interesting for repeat

Table 1. A comparison of different methods for simulating a patient encounter. all of these techniques have been called "virtual patients" though the term is most commonly associated with interactive patient scenarios. Estimations in this table are author opinions based upon experience developing simulated medical encounters.

	Case Presentations	**Interactive Patient Scenarios**	**Virtual Patient Game**	**High Fidelity Software Simulations**	**Human Standardized Patients**	**High Fidelity Manikins**	**Virtual Standardized Patient**
Common Names	Online Virtual Patient	Virtual Patient, Multimedia Sim, Branching Scenario	VR Simulation, Virtual Patient Avatar	Medical Simulation, VR Surgical Simulator	Standardized Patient, Patient Actor	Manikin, Task Trainer	Virtual Human, Conversational Agent
Teaching Applications	Basic Knowledge, Clinical Reasoning	Clinical Reasoning	Procedures High-risk scenarios Team Training	Complex Procedures Surgeries High-risk scenarios	Patient History Physical Exam Patient Counseling	Procedures, Team Training	Patient History Patient Counseling
Learner Skills Evaluated	Knowledge, Pattern Recognition	Clinical Reasoning	Clinical Reasoning, Procedural Reasoning Physical Diagnosis	Procedural Skills, Critical Interventions	Interview Skills, Physical Diagnosis	Clinical Protocols, Physical Diagnosis Team Performance,	Interview Skills
Interactivity	Very Low	Low-Moderate	Moderate-High	High	Very High	Moderate	Very High
Consistency of Experience & Evaluation	High	High	Moderate	High	Very Low	Low-Moderate	High
Flexibility to Recover from Learner Errors	None	Low	Moderate	High	HIgh	Moderate	High
Suitable for Game-based approach?	None	Moderate	High	Moderate	None	Low	High
Authoring Challenge	Low	Moderate	High	Very High	Low	Moderate	High
Core Technology	Text, Multimedia	Branching, Multimedia	State-machines, Branching	Physiology Engine, Virtual Reality Tissue,	None	Varies	Dialogue AI, Natural Language
Enabling Technology	HTML, Authoring Tools	HTML, C, Action-script, etc., Authoring Tool	Game Engine	Game Engine, Anatomy Database, Haptic Controllers	Written Script, Video Recorder, Human Monitor	Microcontrollers, Sensors & Actuators, Wireless Data	3D Game Engine, Speech Synthesis, Non-Verbal Behavior, Speech Recognition

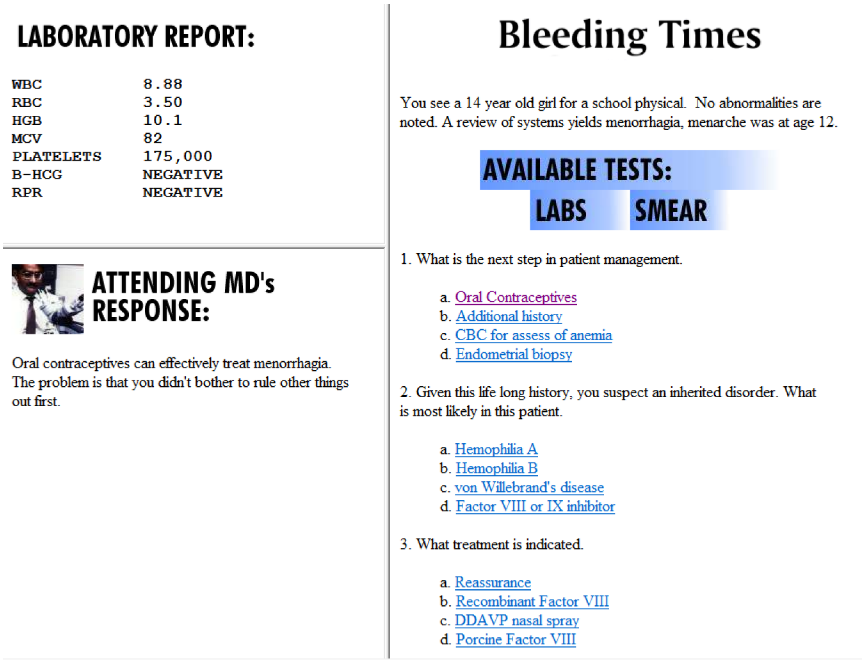


Figure 1. A case presentation. Calling this example of a multimedia case presentation a virtual patient is a stretch. There is a brief case description followed by multiple choice questions. Innovations to be found in this old teaching case include random question access and simultaneous viewing of the case narrative, questions, data & feedback. Each question response generates specific feedback to the learner. From Bleeding Times: An Introduction to Coagulation (Talbot, 1997).

play if the choices provided result in differing patient outcomes, though most branching interactive scenarios tend to drag the learner along a fixed path to maintain consistency for the next phase of the encounter and to lower the content authoring burden.

There has been a great deal of innovative work in the area of interactive virtual patient scenarios. The MedBiquitous consortium has created a national virtual patient standard (ANSI/MEDBIQ VP.10.1-2010) that includes an XML-based schema that is intended to offer universal playability and assessment reporting of virtual patient cases. The schema separates virtual patient data, media resources, activity models, data availability models and a global state model in a standardized fashion. The separation of data types allows for the creation of a wide variety of both linear and branching interactive patient scenarios with a wide variety of embedded multimedia (Ellaway & McGee, 2011). Additionally, there are several commercial and open source virtual patient authoring tools that work with MedBiquitous cases such as the CAMPUS, CASUS, OpenLabyrinth, vpSim and WebSP authoring systems. Although it is intended to be a standard, incompatibilities between authoring systems and players still exist, especially for branching scenarios and higher end multimedia such as videos and interactive animations (Hege, Kononowicz, Pfahler, Adler, & Fischer, 2009). Ongoing progress with open standards IPS virtual patients is evaluated periodically at the MedBiquitous annual conference.

The most ambitious example to employ standards-based interactive patient scenarios so far has been the European Union's eViP (electronic virtual patient) project. From 2007 to 2010, the eViP project established a research consortium that built a MedBiquitous compliant online resource center and virtual patient repository. The eViP team created and tested more than 300 virtual patient cases that are available to anyone under a Creative Commons license (www.creativecommons.org). The eViP team conducted a number of large surveys whose reports contain a wealth of information on virtual patients. The cases and reports are available online at the eViP website (eViP Project Team, 2012).

The game play of branching virtual patient scenarios is very similar to text-based adventure games though medical scenarios to be shorter experiences that last between ten and fifteen minutes. Even though IPS virtual patients are relatively primitive compared to video games, they are still significantly burdensome to author. Research shows that production of these kinds of virtual patients historically costs $10,000-$50,000 dollars over an average of 16 months. At this cost, authors are able to provide peer-reviewed case content that provides direct performance feedback. Unfortunately, only 20% of US medical schools author cases that feature branching to enable multiple outcomes contingent on learner outcomes (Huang, Reynolds, & Candler, 2007). These results are discouraging and they show that medical schools have been inefficient at producing content that offers significant interactivity and game play for learning. Fortunately, a new generation of tools are becoming available that have the potential to significantly reduce the authoring burden of IPSs, especially for branching scenarios (Benedict, 2010; Ellaway, 2010). Through use of newer tools and repurposing extant IPS scenarios, there are reports that IPS-style virtual patients have been created in as few as 20-80 hours (Poulton & Balasubramaniam, 2011). New research is needed to assess how much time and money needed to produce interactive patient scenarios has declined and if use of branching and other game-like features has increased since the introduction of more advanced authoring tools.

Virtual Patient Games

Virtual Patient Games (VPGs) are also known as Virtual Patient Avatars, Virtual Patient Simulations (VPSs) and Virtual Reality Simulators. They come directly from the traditional video game world and consist of a three dimensional character within some type of medically relevant environment. They are usually based on a licensed video game engine. These kinds of medical simulations and virtual patients are commercially available from a variety of sources. Many virtual world and game platforms have been used for medical education including VBS2 (Bohemia Interactive Simulations), Second Life (Linden Labs), OLIVE (SAIC Corp), Unity 3D (Unity Technologies), Unreal (Epic Games) and many others. As of this writing, there are three game platforms specifically designed and marketed for medical training. Each features a complete game engine, medical training scenarios, built-in human physiology models, visually demonstrative 3D avatars, patient data displays, the ability to perform medical procedures and assessment reporting capabilities (Table 2).

The vHealthCare platform (Breakaway Ltd) builds upon a considerable Defense Department investment with Breakaway Ltd and Texas A&M University on an advanced virtual reality medical simulator called Pulse!! The vHealthCare content targets nursing, dental and medical students. It features single player video game-like training scenarios that emphasize medical emergencies and use of diagnostic tests. The platform is noteworthy for a very complete and demonstrative physical exam capability as well as metric-based and expert comparison learner feedback. VHealthCare has a variety of authoring tools and has been validated through a large number of research studies. Currently a single player system using a custom engine, vHealthCare is being upgraded to multiplayer, web browser delivery and the Unity engine (Cheek, 2012).

The HumanSim platform (Applied Research Associates) is built on the Unreal 3 game

Table 2. Comparison of three purpose built virtual patient game platforms. Data is based upon a survey of vHealthcare by Breakaway Ltd, HumanSim by Applied Research Associates and the Clinispace Dynapatient by Clinispace. Each company responded directly to a written survey for this article (Cheek, 2012; Heneghan, 2012; Dev, 2012). Besides these, a number of game engines have been adapted for medical training simulations.

	vHealthCare	HumanSim	Clinispace
Heritage	DoD / Texas A&M Pulse!!	"Body Simulation" Engine	Dynapatient in-silico models
Audience	Nursing Schools Pharmaceutical Training Dental & Medical Students Medical Education Publishers Medical Device Manufacturers	US Army Medical Residents Medical Students Paramedics Medical Centers Nursing Schools	Graduate Nursing Military Medic Triage General Medical Training
Completed Training Scenarios	Trauma, Med-Surg, ER, Patient Interview/Assessment, Pulmonary Embolism, Pericarditis, Bleeding Ulcer, Dental Implants, Coronary Syndromes, Military Nurse Pre-Deployment	Anesthesia, Pneumothorax Maternal Hemorrhage, Triage & Assessment, Paramedic Response, Team STEPPS Certification, Team Training	Trauma, Sepsis, Ventilator use, Pre-surgery, Neonatal Resuscitation, GI pain, Triage, Physician Reporting
Physiology Model	Modular State Machine, Physiology Engine Plug-ins	Advanced High Fidelity General Physiology Engine	State & Variable Based Models, Age/Sex Specific Models
Spoken Dialogue	Recorded Voice, Text to Speech	Recorded Voice, VOIP	Recorded Voice
Automated Interactive Dialogue	Multiple Choice Conversation Designer	Branching	No
Natural Language Understanding	No	No	No
Procedures	Airway, Vascular Access, Rectal Exam, Dental Implants, Heart Catheterization	Airway, Anesthesia (detailed), Vascular Access	Chest tube, Airway
Assessment	Task Completion Metrics, Expert Benchmark Comparison, Quizzes	Interactive After Action Review, Cognitive Decision Evaluator, Recording with viewer	Action Recording SQL Database, Milestone Checklist
Multiple patients	No	Yes	Yes
Multiplayer	No	Yes, up to 50	Yes
Authoring Tools	Yes	In Development	Clinispace Nursing
Platforms	PC (Web pending)	PC, Web, (iOS & Android pending)	PC, Mac, Web, iOS, Android
Validation Studies	11 Controlled Studies	Validation Study Underway	3 Studies Underway

engine combined with a sophisticated physiology engine with a significant heritage (Figure 2). Although much content on the platform focuses on patient assessment and emergency response, HumanSim is especially suited to airway and anesthesia specific applications. Training applications also focus on team skills building as HumanSim includes support for large numbers of patients and human participants within the same scenario. Assessment is provided through an interactive after action review and a cognitive decision evaluator. A validation study of an anesthesia application is underway at Duke University Medical Center (Heneghan, 2012).

The third platform, Clinispace, uses a lightweight implementation of the Unity 3D game engine on a wide variety of online platforms. Clinispace applications focus on graduate nursing, military medic triage and other general medical training, including neonatal resuscitation. Clinispace lacks the broad physiology engines of the other two platforms but includes several state and variable based physiology models focusing on sepsis and hemorrhage. Another unique feature of the Clinispace virtual patients is that its physiology models are age and sex specific. The platform is multi-patient and multiplayer capable. Assessment is done via action recording and feedback is provided through a milestone checklist. Three validation studies of Clinispace are in progress (Dev & Heinrichs, 2012).

Virtual Patient Game platforms share a number of important limitations. First, they are difficult and somewhat expensive to develop material for. Training content is not directly author-able by medical educators and content must be programmed by the platform's developers. Second, the avatars may be capable of playing recorded sound or speech, but they do not understand natural language and are not capable of conversational interaction. This is an important limitation because most clinician-patient interactions consist of verbal discourse. In the authors' opinion, another limitation is that Virtual Patient Game avatars are sometimes overwhelmed by the learner attending to the menu systems or the patient monitor

Figure 2. A virtual patient game environment. This environment looks like a commercial video game and is based off of the Unreal 3 engine. Note the presence of the patient physiology monitor, a patient on procedure table and numerous non-player characters. HumanSim image courtesy Applied Research Associates.

displays. The end result can be that the patient avatar's presence is practically superfluous. Also, VPGs that are driven by branching logic are often unforgiving of learner errors as it is difficult to design them to recover gracefully from learner mistakes. Given the complexity of VPG systems, it is very important to manage learner cognitive load, which can easily exceed the learner's attention limit (Cook & Triola, 2009; Mayer, 2001).

VPGs excel in the development of clinical reasoning, procedural reasoning and physical examination skills. They leverage interactive branching scenarios with a video game front end that is visually appealing and immersive. They provide a safe medical sandbox to engage in high-stakes situations without risking the health of a patient (Jana, 2006). Additional advantages of using a game engine based approach to the virtual patient lies in the game play potential. VPGs can be invoked in a simulated emergency room or plane crash. VPGs can even be instantiated into combat exercises and other scenarios that commercial game engines are good at and thus allowing the Virtual Patient Game to be part of a larger game-based training environment (Dunne & McDonald, 2010).

High Fidelity Software Simulations

High fidelity software simulations (HFSSs) are another type of virtual patient that can be distinguished by a real-time simulation of human physiology and a high degree of precision. A classical HFSS application is the anesthesia simulator. Such a simulator includes a real-time physiology engine that responds realistically to a variety of patient conditions and pharmacological interventions. The interface will always include patient data displays that show breathing, heart, oxygenation and the like. The presence of a patient avatar or use of a game engine is completely optional, though some VPGs may also count as high fidelity software simulations.

Some high fidelity software simulations are quite abstract. The SIMapse Nerve Agent Laboratory, used by the US military, depicts cholinergic nerve physiology in a kinetic graphical manner and responds accurately to a variety of interventions while imagining a live simulation at the cellular level. Strangely enough, it plays like a video game so much that the author has seen pre-school children play it for over fifteen minutes. This simulator does not even directly show a human patient (Talbot, 2009).

Another type of high fidelity software model includes virtual reality (VR) surgical simulators. VR surgery simulators employ 3D engines with accurate anatomy information and tissue property data to create views that may be external or internal to the human body. Such systems allow the learner to rehearse dangerous surgeries in a risk-free setting. Some VR surgical trainers include stereoscopic displays and haptic-feedback enabled controllers that permit the learner to feel the operation (Liu et al., 2005). One constant is that VR surgical trainers generally do not show the entire human and they do not include other capabilities associated with VPGs.

High Fidelity Manikins

There are a number of commercially available manikins that include features seen in interactive branching scenarios and VPGs, but they are generally not described as virtual patients. They have realistic anatomy and employ electric actuators so that they appear to breathe, have pulses and blood pressure, blink eyes, secrete, bleed and have cardiac electrical activity. A few invasive procedures can be performed on them. Some also include branching state machines and physiology models but most of the time they are controlled by a human operator. There is no built in way to elegantly 'set up' a manikin scenario for learners and unlike VPGs, manikins have surprisingly little variety of expression (Talbot, *in press*). Comparative qualities of high fidelity manikins are included in Table 2.

Human Standardized Patients

Human Standardized Patients (HSPs) have been considered to be the gold standard medical education experience for both learning and evaluation purposes (Collins & Harden, 1999;

Adamo, 2004; Jack et al., 2009). HSPs are paid actors who pretend to be patients for educational interviews or they are patients with physical findings who are paid to receive physical examinations. HSPs provide the most realistic and challenging experience for those learning the practice of medicine because they can most closely approximate a genuine patient encounter. HSPs are without peer in the evaluation of physical examination techniques. HSPs are also a key component in medical licensing examinations.

HSP encounters engage a number of clinical skill domains such as social skills, communication skills, judgment, and diagnostic acumen in a real time setting. When it comes to these interviewing skills, other kinds of practice encounters fall short because they either do not force the learner to combine clinical skill domains or they spoon feed data to the student with the practice case turning more into a pattern recognition exercise, rather than a realistic clinical problem solving experience.

Despite the well-known advantages of HSPs, they are employed sparingly due to the high expense of hiring and training actors (Parsons et al., 2008). Moreover, the actors themselves are typically low skilled and administrators face constant turnover resulting in considerable challenges for maintaining the consistency of diverse patient portrayals for training students. In practice, HSPs will often provide verbally correct answers but the accuracy of their responses can be as low as 30% (Tamblyn, Klass, & Schnabl, 2009). This limits the value of this approach for producing realistic and valid interactions needed for the reliable evaluation and training of novice clinicians. Thus, the diversity of clinical conditions that standardized patients can characterize is limited by availability of human actors and their skills. This is even a greater problem when the actor needs to be a child, adolescent, elder, person with a disability or in the portrayal of nuanced or complex symptom presentations.

The imposition of recording has been reported to have demonstrable effects that may confound the end goal of clinical training (Bogolub, 1986) and the supervisor review of raw recordings is a time consuming process that imposes a significant drain on resources. In addition, other sources of unreliability and bias in HSPs have been reported (Tamblyn, Klass, Schabl, & Kopelow, 1991). The most common complaints about HSPs that the authors have heard in medical student focus group encounters are the limited opportunities to use them and inability to repeat an encounter. They also complain about the lack of detailed performance feedback and the students' perception of bias by the HSP or observer.

Virtual Human Conversational Agents

Recently, seminal research and development has appeared in the creation of highly interactive, artificially intelligent and natural language capable virtual human (VH) conversational agents. No longer at the level of a prop to add context or minimal faux interaction in a virtual world, these VH agents are designed to perceive and act in a 3D virtual world, engage in face-to-face spoken dialogues with real users (and other VHs) and in some cases, they are capable of exhibiting human-like emotional reactions. Previous classic work on virtual humans in the computer graphics community focused on perception and action in 3D worlds, but largely ignored dialogue and emotions. This has now changed. Artificially intelligent VH agents can now be created that control computer generated bodies and can interact with users through speech and gesture in virtual environments (Gratch, Rickel, Andre, Cassell, Petajan, & Badler, 2002). Advanced virtual humans can engage in rich conversations (Traum, Marsella, Gratch, Lee, & Hartholt, 2008), recognize nonverbal cues (Morency, de Kok, & Gratch, 2008), reason about social and emotional factors (Gratch & Marsella, 2004) and synthesize human communication and nonverbal expressions (Thiebaux, Marshall, Marsella, Fast, Hill, Kallmann, & Lee, 2008). Such fully embodied conversational characters have been around since the early 90's (Bickmore & Cassell, 2005) and there has been much work on full systems to be used for training (Evans, Hearn, Uhlemann, & Ivey, 1989; Kenny, Rizzo, Parsons, Gratch, & Swartout, 2007; Prendinger & Ishizuka, 2004; Rickel, Gratch, Hill, Marsella, & Swartout, 2001; Rizzo et al., 2011), intelligent kiosks (McCauley & D'Mello, 2006), and virtual receptionists (Babu, Schmugge, Barnes, & Hodges, 2006).

In this regard, *Virtual Standardized Patients (VSPs)*, a specific kind of virtual human conversational agent, can be used in the role of standardized patients by simulating a particular clinical presentation with a high degree of consistency, credibility and realism (Stevens, Hernandez, & Johnsen, 2005), as well as being always available for *anytime-anywhere* training. There is a growing field of researchers applying VSP's to training and assessment of bioethics, basic patient communication, interactive conversations, history taking, clinical assessments, and clinical decision-making (Bickmore, & Giorgino, 2006; Bickmore, Pfeifer, & Paasche-Orlow, 2007; Lok et al., 2007; Kenny et al., 2007; Parsons et al., 2008; Rizzo et al., 2011). Initial results suggest that VSPs can provide valid and reliable representations of live patients (Triola et al., 2006; Andrew et al., 2007). VSP applications can likewise enable the precise stimulus presentation and control (dynamic behavior, conversational dialog and interaction) needed for rigorous laboratory research, yet embedded within the context of ecologically relevant simulations of clinical environments (Kenny et al., 2007; Parsons et al., 2008; Andrew et al., 2007).

VSP systems require a complex integration of technologies. A general VSP architecture can be created to support a wide range of verbal interaction levels from simple question/answering to more complex approaches that contain cognitive and emotional models with goal-oriented behavior. Such architectures are modular distributed systems with many components that communicate by message passing. Each module may contain various subcomponents. For example, the natural language section is divided into three components: a part to understand the language, a part to manage the dialog and a part to generate the output text. This is all combined into one statistical language component. Interaction with the system might require that user enters text as input or talks into a microphone that records the audio signal that is sent to a speech recognition engine. With voice recognition, the speech engine converts that into text. The text is then sent to a statistical response selection module. The module picks an appropriate verbal response based on the input text question. The response is then sent to a non-verbal behavior generator that selects animations to play for the text, based on a set of rules. The output is then sent to a procedural animation system along with a pre-recorded or a generated voice file. The animation system plays and synchronizes the gestures, speech and lip-syncing for the final output to the screen. The user then listens to the response and asks more questions to the character.

Due to strengths of their dialogue system AI, VSPs excel at interview and counseling skills applications. Additionally, VSPs can be constructed so that they provide features not found in human standardized patients such as reliable, bias free assessments with detailed reporting to the learner and the possibility of repeated performances. Extensive work has been conducted on full feature VSPs by the USC Institute for Creative Technologies MedVR group (Rizzo et al, 2011). The Virtual Experience Research Group (http://verg.cise.ufl.edu) at the University of Florida also builds dialogue AI systems and virtual patients (Rossen, Cendan, & Lok, 2010).

ACHIEVING NATURAL LANGUAGE DIALOGUE WITH VIRTUAL PATIENTS

Despite several decades of work on artificial conversational agents, building machines that can come close to mimicking the human language ability in general unconstrained conversation remains largely out of the reach of current artificial intelligence and natural language processing. This is one of the problems that came to be known informally as AI-complete, and is also a central piece of the Turing Test

(Turing, 1950). Substantial progress has been made, however, in constrained scenarios where the vocabulary and topics of conversation are limited, allowing for the creation of artificial agents that interact with users for specific purposes, such as providing information or participating in training simulations. Fortunately, Virtual Standardized Patient interviews fit well into a constrained scenario.

Although early work on conversational agents produced entertaining results, such as the well-known ELIZA program (Weizenbaum, 1966) and its various descendants, chat-bots based on these techniques act based on simple pattern matching rules, without a purpose or general coherence that takes user input into account over the course of a dialogue. Current work on intelligent conversational agents far surpasses the capabilities of early chat-bots, endowing machines with language and reasoning abilities based on statistical modeling, natural language processing, theories of discourse structure and various forms of artificial intelligence. Much of this work falls within the field of dialogue systems research, which overlaps with artificial intelligence (AI) and natural language processing.

Artificial Intelligence Dialogue Systems

Within the broad spectrum of dialogue systems, which includes for example telephone-based voice-enabled airline reservation systems, Google Voice and Apple's SIRI, conversational virtual human dialogue systems are of particular relevance to virtual patients. Virtual humans are embodied agents that communicate through verbal (language) and nonverbal (gestures, facial expressions) channels. The natural language and dialogue technology that powers virtual humans is varied and often selected or developed to match the characteristics of particular applications. If the interaction between the virtual human and human user is tightly scripted, such that user utterances are restricted to a finite set of choices that is presented by the system, approaches such as finite state control using call flow graphs (Pieraccini & Huerta, 2005) and branching narrative for interactive games (Tavinor, 2009) are sufficient. On the other hand, if more varied natural language input is to be expected by the virtual human, one general technique that is widely used and is well matched for virtual humans that provide information by answering questions about a certain topic (e.g. a product, a company, or a website) is to model the correspondence between arbitrary questions within the relevant topic to a finite set of predefined answers. A specific technique that accomplishes this modeling task is that of cross-lingual information retrieval, which is applied to this question-answer mapping by treating questions as information queries in one language, and answers as documents in a different language (Leuski & Traum, 2010). This approach generalizes over the set of questions so that questions that the system has never encountered before can be matched to the most relevant answer from the predefined set, much like queries to a search engine are matched to documents in a collection. This has been used successfully in deployed virtual human systems ranging from museum guides at the Museum of Science in Boston (Swartout, Traum, Artstein, Noren, Debevec, Bronnenkant, & Williams, 2010) and virtual patients (Kenny, Parsond, & Garrity, 2010) to promotional characters for the US Army (Artstein, R., Gandhe, S., Leuski, A. & Traum, 2008; Leuski, Kennedy, Patel, & Traum, 2006) and guides in virtual worlds (Jan, Roque, Leuski, Morie, & Traum, 2009), such as Second Life.(Figure 3).

Although much can be accomplished in practice using agents that either limit user input in exchange for coherence over a long dialogue, or with question-answer agents that handle free input, but only one question at a time, these approaches sacrifice important conversational aspects of dialogue to achieve robustness in different ways. More sophisticated approaches to dialogue management take a more nuanced approach, making these trade-offs in more graded fashion to achieve acceptable levels of both understanding of natural language without a set of fixed choices and coherence over lon-

Figure 3. A virtual standardized patient. The virtual human presented here is capable of natural language understanding and can carry on two way verbal conversations within the boundaries of a medical interview. The entire upper body is presented on screen because the virtual human will exhibit a variety of non-verbal behaviors which include facial expressions, posture and hand movements. "Virtual Sick Call" image courtesy USC Institute for Creative Technologies.

ger conversations about a specific topic. This is generally accomplished in part by a Dialogue Manager, which serves as the brain of a virtual human, tracking its state through the interaction and its knowledge, and deciding what it should do or say depending on user input and the virtual human's own goals. By combining techniques used for the question-answer agents discussed above with suitable dialogue management, virtual humans can be created for tasks such as training in interrogation and questioning related to specific incidents, as in the TACQ virtual human dialogue system (Gandhe et al., 2008). These types of interaction can be both rich and coherent, but are heavily driven by user questions. The addition of interaction goals and inference capabilities to the dialogue manager allow for interactions with mixed initiative, where topics of conversation can be brought up by either the user or the system. One system that uses this style of dialogue management is the SimCoach virtual human system (Rizzo et al., 2011; Morbini, DeVault, Sagae, Nazarian, Gerten, & Traum, in press), where virtual characters attempt to create rapport with military users to encourage exploration of health care options related to PTSD and depression. In this system, it is important for the virtual human to take the initiative and lead the conversation when necessary, but to give users enough room to change the topic or express themselves more freely than in a system with limited choices for user input. Other more sophisticated systems aim to model human language, planning and reasoning skills, as well as emotion, using dialogue managers based on a cognitive architecture (Traum et al., 2008). Such systems allow for rich behavior and multiparty interaction, but authoring of new content and new interaction scenarios is a challenging task that can be performed only by dialogue system experts. In comparison, new characters for new scenarios under the TACQ and SimCoach platforms mentioned above can be authored by domain experts, as opposed to dialogue system experts, or simply by creative writers (Gandhe, Taylor, Gerten, & Traum, 2011).

Low Technology Approaches to Dialogue Play

One method of making a conversation much easier to author and avoiding the complex technology of dialogue systems is to employ multiple choice prompts that either drive video clips or a virtual character dialogue. The Virtual Child Witness (VCW) project at USC Institute for Creative Technologies modeled the rapport building phase of an investigative interview. Users select a series of multiple choice prompts that vary in their open-endedness and therefore in their productivity in eliciting narrative reports. The project was intended to demonstrate, through a virtual child, the varying effectiveness of different question types at inducing detailed accounts during the narrative rapport phase of an investigative interview. Pilot data has supported the program's efficacy in assessing the user's interviewing skills and in serving as an engaging device for training. Students are able to adjust their specific questions in real time in response to the answers and behavior of the virtual child. Both real-time and post-interaction feedback can help guide the individual student toward an optimal interview approach (Lamb, Orbach, Hershkowitz, Esplin, & Horowitz, 2007). While VCW is a linear scenario, ICT has also employed branching multiple-choice based dialogue for the INOTS project. INOTS is a training system to rehearse Navy officer leadership and interpersonal skills. The branching conversations can result in dramatically different outcomes that depend on the learner's selections. Due to a well written narrative along with mutually exclusive and intentionally imperfect user choices, scenarios have great replay value despite the simple AI used to create them (Campbell et al., 2011).

Another method of driving simulated conversations without a dialogue engine is to employ menu based prompts. The Vision project (Breakaway Ltd) is a serious game designed to help eyeglass salespeople learn to advise customers and sell upgrades through rehearsed virtual character interactions. The interface includes two graphing indicators; one for customer mood and another for resistance (Figure 4). These graphical indicators are simple but they really contribute to the game play of the training scenario (Cheek, 2012).

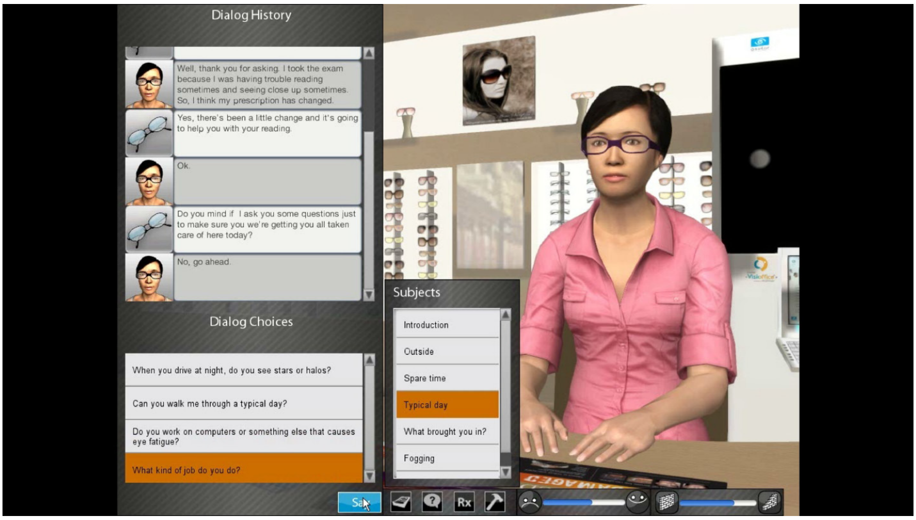
BUILDING A BETTER VIRTUAL PATIENT FOR CLINICIAN LEARNERS

The physician-patient encounter has a number of different elements, as do similar encounters performed by allied health professionals. The recreation of these elements may be better served by some of the approaches discussed in this article than others. The phases of a physician clinical encounter include the interview, the physical examination, labs and radiology, diagnosis, the medical treatment plan, procedures, and patient counseling. Additionally, clinicians in training may be expected to present the patient case or be quizzed on aspects of it. Up front, this section is based upon author opinions as a clinicians, medical doctors and simulation developers. Further research is needed to validate specific simulation modalities for their suitability to substitute for the human patient experience.

The interview is highly dependent on social skills and diagnostic acumen. The gold-standard for interviews is either practice with real patients or human standardized patients. The best virtual patient approach to the interview is with Virtual Standardized Patients, whether they are based on multiple-choice or natural language understanding, VSPs are unrivaled. The medical interview is very well suited to AI dialogue systems because they are human question / computer answer oriented so it is easy to provide boundaries to the encounter. The ability to handle rapport building, open ended and close ended questions requires a considerable amount of development. Some have suggested crowd-sourcing and repurposing existing dialogue sets to make future VSPs easier to author (Rossen & Lok, 2012; Rossen et al., 2010).

The physical examination requires cognitive knowledge of when it is appropriate to conduct a particular exam as well as procedural

Figure 4. A virtual character conversation. The Vision project uses a simple method of topical menus to create dialogue without use of extensive artificial intelligence. Aside from avatar motion, feedback is provided through a dialogue script and two virtual character response meters at the bottom of the screen. Courtesy Breakaway Ltd.



knowledge to correctly perform the examination maneuvers and to interpret exam findings. The gold-standard is a real patient encounter or a human standardized patient. No virtual patient can yet substitute for training or testing the procedural knowledge of the physical exam, though a limited subset of the exam can be practiced on high-fidelity manikins. Virtual patients can address the cognitive aspects and the interpretation of results. The best virtual patient platforms to address these are Virtual Patient Games, using their high fidelity graphics systems, and Interactive Patient Scenarios that can be used to show photographs of physical exam findings.

Laboratory Tests and Radiographs consist of numeric and graphical information. There is a cognitive component to selecting the appropriate tests and interpreting the results. Viewing and interpreting a radiograph is another skill that can be evaluated. Labs and radiographs are easily simulated in most kinds of virtual patient encounters. The most suitable include Case Presentations, Interactive Patient Scenarios, Virtual Patient Games and High Fidelity Software Simulators.

Deciding on and rendering a diagnosis can easily be accomplished through a text-like interface by either entering the diagnosis or selecting from available options. Case Presentations and Interactive Patient Scenarios often ask for the learner to select a diagnosis. User selection of medical treatments involves clinical reasoning and is well handled by Interactive Patient Scenarios, Virtual Patient Games and High Fidelity Simulation Software.

The conduct of procedures requires a diverse set of skills from knowing when a procedure is appropriate and selecting the best procedure for the situation to the skills involved in conducting the procedure and judgment calls during while the procedure is in progress. Manikins and partial manikins called task trainers are well suited to some of these tasks. Virtual patient approaches that involve procedures are best accomplished with Virtual Patient Game platforms and the more surgically oriented High Fidelity Simulation Software programs like VR surgery simulators.

Patient counseling is the phase of the encounter where the physician explains the diagnosis and treatment plan. He will ask for and respond to patient questions, sometimes bargain with the patient and will finally try to gauge patient understanding of the treatment plan. This is a very difficult phase to replicate with a virtual patient, though the Virtual Standardized Patient is probably the best way to go about it. As far as dialogue goes, it involves more of a bidirectional conversation that really pushes current artificial intelligence systems (Traum et al., 2008). The use of virtual patients for counseling scenarios is more experimental and less mature than all other phases of the physician encounter.

A complete simulated clinical encounter may include some aspect that seeks to evaluate learner understanding through some sort of a quiz mechanism. Interactive Patient Scenarios are already built to handle this and similar interactions can easily be built into other modalities such as Virtual Humans. Virtual Humans would likely benefit from the constrained possibilities of multiple choice interactions instead of free-text natural language understanding (Gandhe et al., 2011).

A BOLD FUTURE FOR VIRTUAL PATIENTS

Currently, the virtual patient approaches that are most easily authored by medical educators are case presentations, human standardized patient scripts and interactive patient scenarios. Due to this, we can all expect to see more of these out there than other types of simulated patients. Virtual patient game platforms and virtual standardized patients are at the high end of authoring difficulty. Future progress must be made to develop rich, guided authoring tools that will allow medical educators, not just computer scientists, to develop virtual patients for these more sophisticated systems.

Each type of virtual patient has its advantages. It is up to curriculum developers and medical educators to make the most responsible use of this technology. If they understand that they can create better content directly rather than through intermediaries (Rossen et al., 2010) they will do so if appropriate tools are created that allows for this. They will be best served if they understand the differences between the virtual patient approaches presented in this article and always select the solutions that best fit their learning objectives, assessment strategy and available resources. Finally, we all owe a debt of gratitude to the video game community that has provided the technology cast offs which now enables this new spectrum of virtual patient capabilities. Virtual patient creators will also do well to understand how video games motivate and reward people as well as how they use game play dynamics to engage the user and draw them into repeat experiences.

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