Interactive Digital Patient for Triage Nurse Training

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Abstract

We present a prototype of a Digital Patient (DP) to serve as an interactive virtual reality training tool for nursing students. Our system allows a nurse to verbally interview, observe, and examine a digital patient in a way similar to how one would interact with a real patient. In this paper, we describe the details of the system and report on a preliminary feasibility study performed with a group of six student nurses. Each participant interacted with a DP afflicted with chicken pox. After their sessions with the DP, the participants answered a series of questionnaires and a short interview to determine their evaluation of the DP as a useful training tool. All the participants were able to successfully interview the DP and produce an initial assessment of their condition. We found that the nursing students thought the DP would be a helpful system for gaining practical experience in interaction with patients. Further research will focus on improving the system's communication, expanding it with a library of diseases, and adding evaluation functionality to the DP in the form of an intelligent tutoring system.

1 Motivation

Triage refers to the initial interview of a patient who has arrived in the emergency room (Sharma, 2004). This interview is meant to assess the priority level of a given patient's ailment. At most hospitals, a triage system is staffed by registered nurses who perform the initial screening. The triage nurse evaluates the nature and seriousness of each patient's complaint and effects a disposition for care based on this assessment. The challenge is to assess the patient correctly in a limited time frame, while at the same time establishing a critical rapport with the patient as the first representative of the hospital he or she may speak with.

One common method by which these skills are practiced and trained include students practicing on each other and standardized patients (trained actors who pretend to be afflicted with a particular disease). Also common is the use of written case studies, which use textual descriptions and sometimes images to present situations for the student to interpret. Practicing with real people is often expensive or difficult to arrange and does not guarantee a uniform training experience. Case studies passively provide the information needed to assess a patient, but do not train the nurse in how to extract that information. If a visual component is provided, it is usually in the form of a static image.

Digital Patients (DPs) could offer a number of advantages in providing a strong training experience in triage over practicing with actors, or fellow students, and written case studies. Some of these advantages include providing a consistent training experience, diversity of appearance, race, gender, and age in DP's, and low costs relative to standardized patients. In addition, the use of a DP can ensure that each student receives experience in recognizing diseases rarely encountered in normal clinical practice, such as small pox or anthrax.

Our long-term goal is to build a training tool that provides an interactive, adaptable, and standardized training experience for nursing students in the skills needed for triage and similar patient-interview situations. This tool will include a library of diseases which can be loaded to give the student a wide variety of practice, and will be controllable in terms of the ethnicity, gender, and age of the patient itself. In this paper, we describe our prototype system and present the results of an initial usability study.

2 Related Work

Previous research has established the need for better triage training. Results of a study evaluating students' performance on a simulated clinical encounter with a real human standardized patient indicated that students had the most difficulty obtaining past medical and social history, and displayed a lack of appropriate interviewing skills for

detecting and diagnosing particular medical conditions (Vessey & Huss, 2002). A study determining whether simulation was important in nurse education showed that a limited amount of simulation had a significant effect on the students' performance on an Objective Structured Clinical Examination, enabling them to improve over the control group (Alinier, Hunt & Gordon, 2004). Further research is needed to evaluate strategies that can improve students' communication skills as well as develop intercultural communication skills.

Other research has been conducted using virtual reality (VR) in medical education, simulation, and training. One study evaluating a VR-based intravenous training system showed that 85% of students enjoyed working with the system, 66% improved their confidence with the process of IV catheter insertion, and 68% stated that they would use VR in order to learn other skills (Engum, Jeffries & Fisher, 2003). Simulation systems using both virtual and augmented reality (AR) have been developed to help practioners. One such system includes a set of virtual environments, each representing a patient's home, where the patient's history is determined by examining the environment (Nelson, Sadler & Surtees, 2004).

A prototype was developed to augment a standardized patient with virtual heart and lung sounds, though no formal analysis has been done (McKenzie et al., 2004). The Virtual Medical Trainer system uses 3D patients and other components for training Army medics and physician assistants to retrieve information about various parts of the body by use of a pointing device (Kizakevich, McCartney, Nissman, Starko & Smith, 1998). Virtual Standardized Patients is another training tool with no formal evaluation. It uses natural language processing, behavior modelling, and face modelling, and manages patient history and scenarios. In this system, scenarios are pre-defined but patient-practitioner interaction and dialog is unscripted (Hubal et al., 2000).

One study evaluated a virtual simulated patient system which uses a 3D character with scripted scenarios. This system uses pre-defined queries and textual responses rather than natural language processing for dialog. The study showed that participants rated the system highly, especially as a learning or training tool (Kizakevich, Lux & Duncan, 2003). Another study evaluates a system that uses a virtual human to improve patient-doctor interaction. The study showed that having life-size virtual characters and speech recognition are important for medical training (Johnsen et al., 2005).

Although these and other researchers have proposed the use of virtual reality for training medical students (Mantovani, Castelnuovo, Gaggioli & Riva, 2003), the field of nursing in general and triage in particular has not received the same level of attention in terms of high-tech training solutions. Nonetheless, the recent shift towards using distance learning methods in nursing education (Cook et al., 2004) suggests a potential need for effective computer-based learning methods. Our work will extend this growing technique to a nurse-specific application, with a focus on natural and realistic interaction.

3 Usability Study

We simulated the triage experience by presenting nursing students with a Digital Patient with chicken pox and allowing them to interact with the DP as they would a real patient.

3.1 Participants

Six volunteers were recruited from the School of Nursing at the University of North Carolina at Charlotte. All six participants were female nursing students: three graduate students and three undergraduate students. The three graduate students, or experienced participants, had at least four years of experience as an actual nurse. The three undergraduate students, or novice participants, had less than four years of experience.

3.2 Apparatus

A Pentium IV 2.4 GHz Dell PC with an nVidia GeForce4 Ti 4200 graphics card was used to run the system. The graphics were rendered using OpenGL and voice recognition was enabled using Dragon Naturally Speaking with a noise-cancelling headset microphone. One of Haptek Corporation's interactive 3-D characters was used for the patient (Figure 1). Using Haptek's library, we were able to create our own realistic animations and behaviors including a display of coughing, fatigue, itching, breathing, blinking and other subtle gestures. Textures, behaviors, and responses were developed based on information provided by the Center for Disease Control ("Varicella

Disease," 2003). The character was displayed life-sized on a wall using a Sony VPL-CX5 data projector. Two speakers at the bottom of the projection screen were used to output the sounds from the virtual human and spoken responses generated by Microsoft Text-to-Speech.

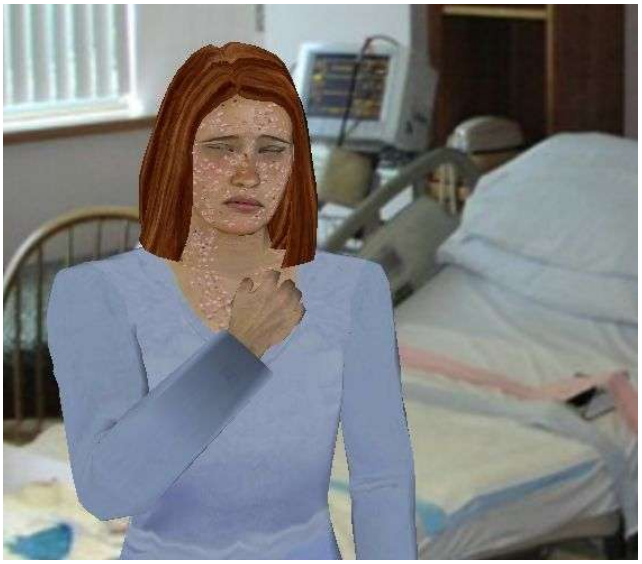

Figure 1: Screenshot of Digital Patient with chicken pox

The phrases recognized by Naturally Speaking were then "read" by a module that classified the sentence based on a search for likely keywords. For example, the string, "How long have you had the rash?" would first be classified as a question based on the keyword "how," then sub-classified as a question about duration based on the keyword "how long," and finally would be noted as having the object keyword "rash." The structure then sent to the cognitive portion of the DP would therefore be a sentence of type QUERY, subtype DURATION, and object "rash," which gives the script the information it needs to respond to the question. This method allows for relatively easy expansion of what type of questions the DP can understand.

3.3 Procedures

Upon their arrival at the experiment room, participants were first asked to sign a consent form. They then created a voice profile using the Dragon Naturally Speaking software. This process took about ten minutes. Once the voice profile was complete, they were asked to dictate a brief selection into a text editor window, in order to get used to the speaking pace at which the speech recognition software best understood them. The participant sat at a desk facing the projected Digital Patient, and wore a headset microphone. She was told to start speaking to the patient in order to obtain as much information about her condition as possible, and to inform the experimenter when she felt she was finished. Once the participant indicated that she was done, the experimenter triggered the end sequence, thereby displaying a dialog box prompting whether the participant wanted to put the patient in isolation and what the possible diagnoses were. After completing this form, the participant answered a series of post-experimental questionnaires and was debriefed.

4 Measures

A series of written questionnaires were given to the participants after using the system. These questionnaires included sections on System Usability, Copresence, and Evaluation of the System. In addition to the questionnaires, an oral interview was also administered.

The System Usability Scale questionnaire, developed at the Digital Equipment Corporation, consists of 10 questions based on a Likert-type scale of 1 (strongly disagree) to 5 (strongly agree). This section of the questionnaire included questions such as "I think I would like to use the Digital Patient frequently." The questions were categorized into four groups: Satisfaction, Simplicity, System Design, and Learnability. Satisfaction measured the extent to which the participant enjoyed working with the system (Brooke, 1986).

The SUS Copresence questionnaire was used to measure the participants' sense of being with the DP (Mortensen et al., 2002). The questionnaire consisted of 18 questions based on a Likert-type scale of 1 (not at all) to 7 (a great deal), including questions such as, "To what extent, if at all, did you have a sense of working with the DP?" and, "To what extent did you feel embarrassed with respect to what you believed the DP might be thinking about you?"

The final section of the written questionnaire addressed specific questions about interaction with the Digital Patient. These items were scored on a Likert-type scale of 1 (not at all) to 7 (a great deal). This section included items such as, "How difficult was it to recognize that the DP had chicken pox?"

In a post-experimental oral interview, the participants were asked sixteen questions to gain further descriptive feedback. These questions were of a more open-ended nature, allowing the participants to provide detailed responses about the advantages and disadvantages of the technology as they had experienced it.

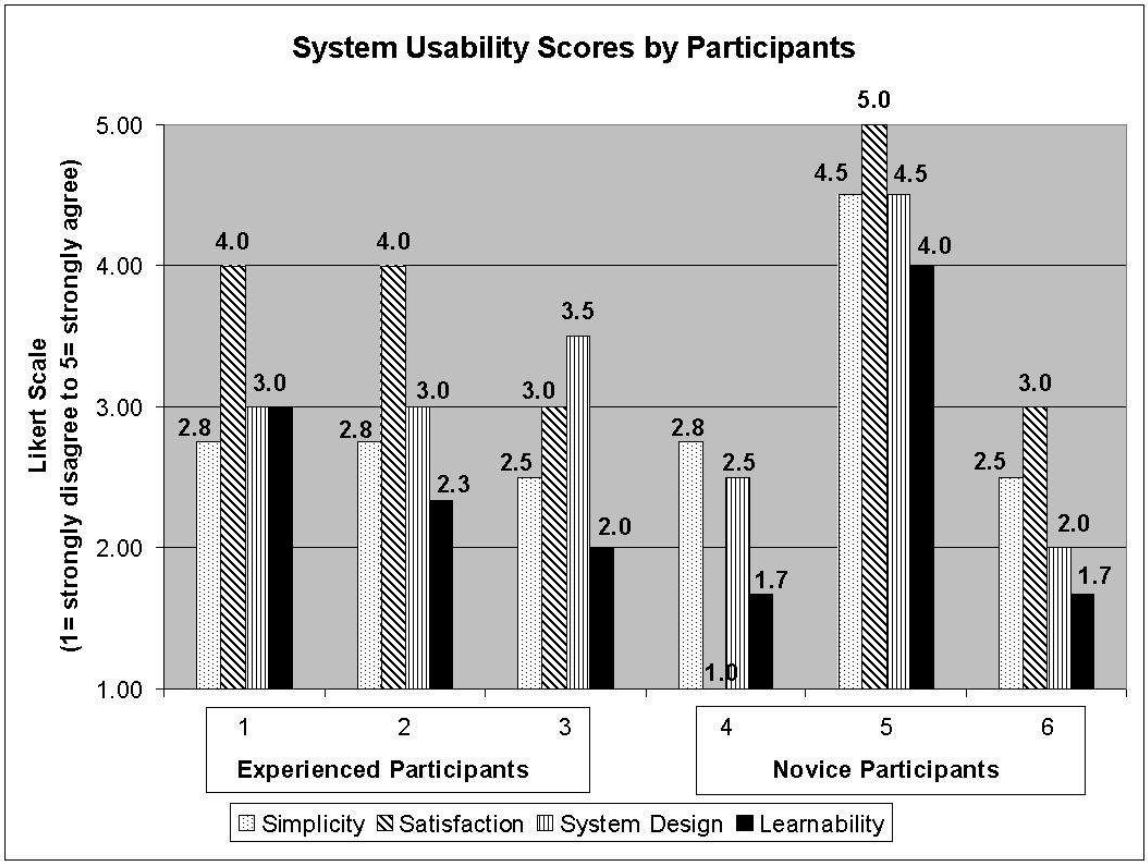

Figure 2: System usability scores by participants

5 Results

5.1 System Usability

System Usability (Figure 2) was evaluated by each nursing student with subscores generated for Satisfaction, Simplicity, System Design, and Learnability. It appeared from the individual scores that nursing experience played a role in how the participants rated the system. All the experienced nursing students rated the DP at or above 3 for Satisfaction and System Design, but at or below 3 for Simplicity and Learnability. The novice participants showed much more variability, with one student evaluating System Usability at four or above on all scales and the other two assigning scores of three or below on all scales.

The participant's comments during the post-experimental interviews were useful in understanding how to interpret the System Usability Scores. Satisfaction was higher for experienced than novice participants. All participants verbally reported that they had difficulty with the patient responding to particular questions that were asked. The novice nursing students saw this as a problem with the system, but the experienced nursing students related this to difficulties they often encountered in communicating with real patients.

The experienced participants were able to reword questions until the patient was able to respond. All experienced participants made comments comparing the interaction with the Digital Patient to experiences with non-native English speakers or children. This is illustrated by the following comments in response to what they disliked about the system:

- "When I asked some questions and she didn't understand. But I have had Hispanics and children that don't understand questions like that."
- "She didn't understand when I kept asking questions, similar to working with children. You have to keep asking and eventually you get it out of them."
- "Having to repeat [the questions]. [It] could have been the way I asked the question, so I tried to reword it. It happens with a few real patients, [such as] those who speak little English or when I catch myself speaking medical jargon."

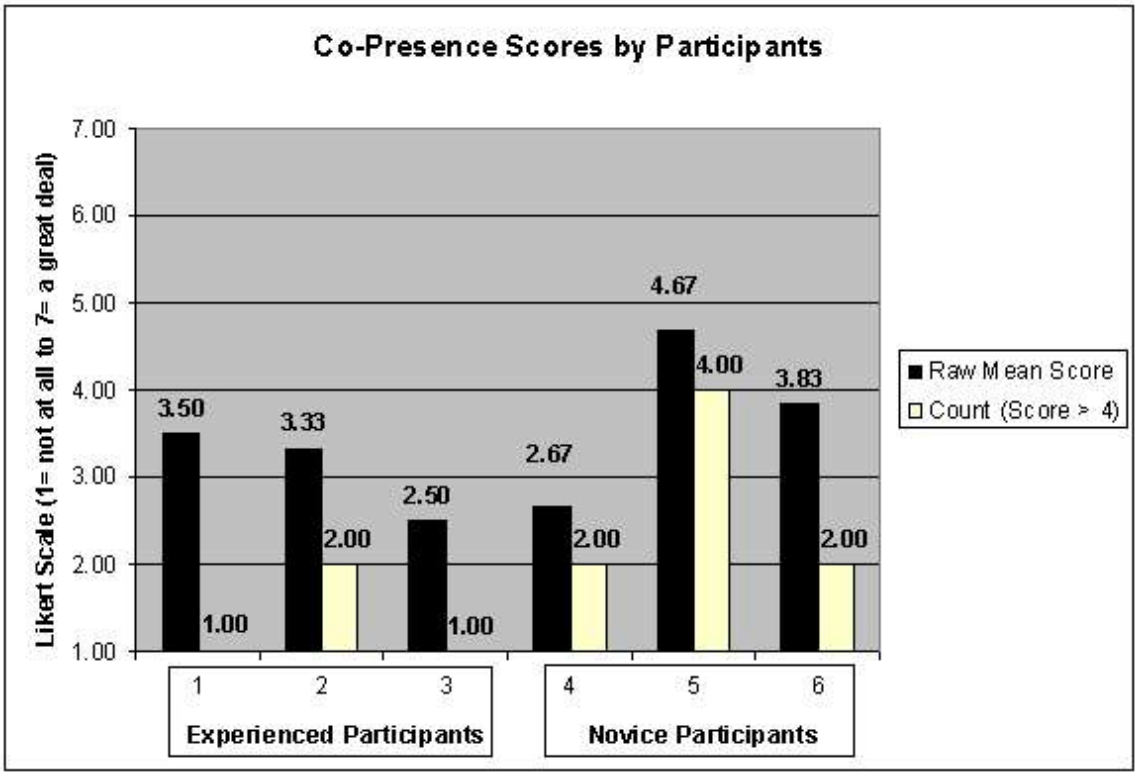

Figure 3: Copresence scores by participants

5.2 Copresence

The raw mean score retrieved from the Copresence survey (Figure 3) measured the extent to which participants felt that they had been interacting with another human being, and the count measured the number of responses that were higher than 4. The scores on the whole were in the middle of the scale, which in practice tends to range from 3 to 5 (Mortensen et al., 2002; Zanbaka, Ulinski, Goolkasian, & Hodges, 2004; Usoh, Catena, Arman, & Slater, 2000).

There seemed to be a slight trend towards higher scores from the novice participants, two of whom reported high copresence. Responses from all of the experienced participants were more average. Comments from the debriefing indicated that participants approved of her appearance and felt that the DP acted like a real person:

- "[The DP is a] good way to teach nursing students because it is interesting with one on one time with the patient, [it] makes them want to learn more."
- "…the sores looked real"
- "I loved the animation, it looked like a real person."
- "I felt like I could talk to her like a real person."

5.3 Evaluation of the Digital Patient

The feedback from our interaction questionnaire (Figure 4) and post experiment interviews indicated that experienced participants rated the DP higher than novice participants. When debriefed, it was clear that the novice participants were frustrated with communicating with the DP and needed a more structured environment. Feedback given concerning this aspect of the DP included the following comments.

- "[The DP is] good for practicing for actual patients but needs more instructions."
- "[The DP is] good for students, [but] should have a disease process for students to follow along at first."
- "[The DP] wasn't answering my questions, but probably it was me not asking the questions right."

All of the experienced participants provided chicken pox as one of the likely diagnoses for the DP. Of the three novice participants, only one provided the correct diagnosis; this participant also tended to rate the DP most positively in all three sections of the measures. This suggests that the frustration felt by the participants, who were unable to diagnose the DP, was reflected in their assessment. It also might suggest that the novice participants were not asking enough of the proper questions to gain a full understanding of the DP's condition. The experienced participants seemed to ask more relevant and precise questions to the patient. The following is an example of the set of questions that an experienced participant asked the DP who determined that the patient might have an adult case of chicken pox:

- "What brings you to the ER?"
- "What happened to your skin?"
- "Do you have nausea?"
- "Do you have night sweats?"
- "Do you have chest pain?"
- [After DP exhibits coughing behaviour…] "How long have you been coughing"
- "Is there someone in your family with the same symptoms?"
- "Is the rash on your entire body?"
- "Have you a loss of appetite?"
- "Are you tired?"
- "Have you been to a place recently where you have never been before?"
- "Have you ever had chicken pox?"
- "Have you been immunized against chicken pox?"
- "When coughing does anything come up?
- "Are your secretions bloody?"
- "Do you have stomach-ache, headache or any other pain?"

The following is an example of the set of questions that a novice participant asked the DP who incorrectly thought the DP was afflicted with measles or the mumps:

- "What are you scratching at?"
- "What brings you to the hospital?"
- "Had you been doing anything you think might have caused the rash?"
- "Have you ever had a rash like this before?"

- "When did you have a rash like this?"
- "Do you have any family here today?"
- "Are there any other complaints?"
- "What else is wrong?"
- [After DP exhibits coughing behaviour…] "Have you taken anything for the runny nose and cough?"
- "Do you understand me?"
- "I forgot your name, what is your name?"
- "How old are you?"
- "Do you go to school anywhere?"
- "Where is the rash at?"
- "Does anybody else you know have a rash like you have?"
- "Who else has this rash?"
- "What are you doing to makes your rash feel better?"

The novice participant asked few questions leading to a proper diagnosis, compared to those asked by the experienced participant.

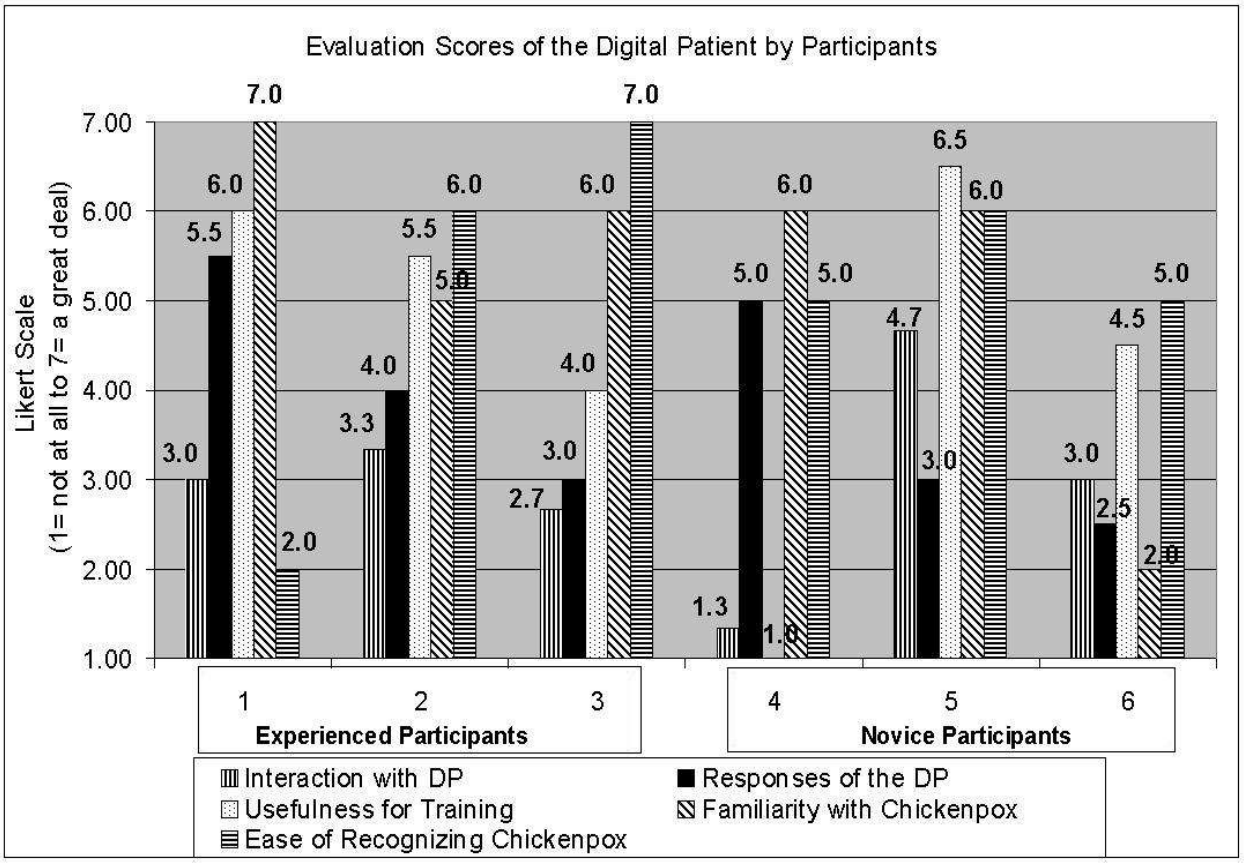

Figure 4: Evaluation scores of the Digital Patient by participants

As a group our participants believed that the DP would be good for practicing and building confidence for interviewing skills. The participants also thought that the DP was good for developing critical thinking skills. The following are some of the participant responses when asked about what some of the potential uses for this technology are and what they liked about the system:

- "For assessment, to give people confidence talking to a patient because sometimes people get intimidated. It helps with getting history and pushes you to develop critical thinking skills because you have to figure out what to ask them and listen to what they say as well as what they don't say."

- "Any area that deals with people or communication."
- "Building confidence and practicing, especially working on patients with diseases you wouldn't normally see."
- "Nursing courses or pathophysiology, and med students because they don't see what we see, they see what we tell them."
- "Critical thinking, had to think back to early nursing experience"

6 Conclusion and Future Work

Our major findings indicate that the Digital Patient may be a useful technology for student nurse training, particularly for novice users. Participants felt that the DP made learning more interesting and would help to reinforce interview skills. The differences in responses between novice and experienced participants suggested that the novices, with less background in dealing with real patients, may have been less patient with the DP than the more experienced nurses. This supports our belief that the DP will help students to develop the skills needed when conversing with real patients, who may be difficult to communicate with at times. Such systems may also help to prepare nurses to work within the field of telemedicine where communication with patients is done through video and audio connections from a remote site. At the same time, limitations in the speech recognition and language processing were frustrating to the participants, thereby damaging the sense of realistic interaction and presence that we are hoping to achieve. These shortcomings in the interaction seem to be the main reason for the mixed responses from the participants about the DP as a whole, although they approved of the concept.

Future work on the Digital Patient will focus on improving its verbal and nonverbal communication with the student, both in terms of the natural language processing and in broadening the responses the DP can provide. While it can be educational for the DP to be less helpful than the student wants it to be, this aspect should be controlled rather than accidental. We also intend to begin building a library of disease scripts and studying the ability of users to differentiate between similar diseases presented by the DP. We will also be adding intelligent evaluation functionality which could analyze the student's progress and weaknesses, thus providing built-in feedback to the user on his or her interview style. This expansion will evolve the DP into an intelligent tutoring system that can teach students rather than simply providing a mode of practice.

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