Lessons Learned in Modeling Virtual Pediatric Patients

Robert C. Hubal, M.S., Ph.D.[1] (rhubal@rti.org)
Robin R. Deterding, M.D.[2] (deterding.robin@tchden.org)
Geoffrey A. Frank, Ph.D.[1] (gaf@rti.org)
Henry F. Schwetzke[1] (hschwetzke@rti.org)
Paul N. Kizakevich, M.S., P.E.[1] (kiz@rti.org)

[1]*RTI International, Technology Assisted Learning Division, Research Triangle Park, NC*
[2]*University of Colorado School of Medicine, Department of Pediatrics, Denver, CO*

Abstract. In two applications the authors are developing virtual pediatric characters for training and assessment. One application, a virtual pediatric standardized patient, is intended for medical school students rotating through pediatrics to train and assess their basic communications and procedural skills while interacting with kids. The other application presents at-risk teenagers with vignettes to assess risky behavior and impulsivity. Both applications rely on existing responsive virtual human technology. The authors are engaged in preliminary clinical trials for the work described in this paper.

1. Background/Problem

Proper interaction skills training and assessment is a difficult, expensive undertaking. Two of the most common approaches are role-playing among students and programs that employ actors, such as standardized patient (SP) programs that evaluate clinical examination skills of student practitioners. These approaches have limitations, though. Role-playing offers few opportunities to repeatedly practice learned techniques, provides little or no individualized tutoring, and often fails to exploit available training technology. Further, role-plays of interactions with children are strained, at best. SP programs are most useful for the evaluation of adult clinical problems but less useful for the assessment of pediatric clinical skills; ethical and reliability issues limit the use of children in SP scenarios.

Advances in responsive virtual human (RVH) technology offer a possible solution. The goals of RVH applications are to increase the realism of virtual role-plays through natural dialog between the user and emotive, active virtual humans; enable repetitive, motivational practice for diverse learners; reduce on-the-job learning of key interaction skills, such as identifying cues given by interaction partners and shifting to strategies most likely to work with a particular individual; and monitor and report on student performance.

We have previously described a virtual standardized patient (VSP) system as an adjunct to live actors for teaching and evaluating patient interviewing skills [1]. We are currently working on a virtual pediatric SP (VPSP) to allow the assessment of a student's ability to communicate and interact with a child and follow protocol in performing a pediatric physical examination (PE). In a concurrent, separate application, we have also developed models of teenage behavior appropriate for assessing the efficacy of intervention programs for adolescent substance abuse.

2. Methods/Tools

The RVH applications are representative of those developed in RTI's Technology Assisted Learning (TAL) division. We define TAL as *proactively applying the benefits of technology to help people train more safely, learn better, retain skills longer, and achieve proficiency less expensively*. We develop TAL applications for jobs requiring complicated knowledge and skills, complex or expensive equipment or work material, a high cost of on-the-job training or failure on the job, jobs where safety or spatial awareness is essential, and for large student throughput requirements [2,3].

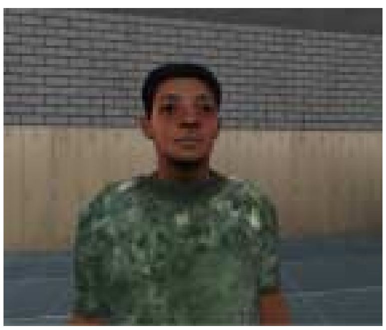
RVH technology employs natural language (NL) processing, virtual reality (VR), and behavior modeling to improve interaction skills training. A responsive virtual human is an intelligent agent that behaves appropriately in a given situation. The agent responds to natural (i.e., not pre-scripted) dialog, its body movement fits its mental and physical state, its facial expression represents emotional state, and its choice of verbal response is contextually appropriate. Thus, the virtual human should act as if it is in a pleasant mood, confused, disengaged, in pain, etc. To develop responsive virtual humans requires modeling several types of behaviors:

- Cognitive. We track world knowledge as is required for each application. For instance, the teenager in our virtual vignettes is there to entice the participant to exhibit or avoid risky behavior, such as keeping stolen goods or attending a drinking party, so it must understand that the participant may and should be trying to avoid the enticement. Our virtual humans also reason about social roles and conventions, such as what can be stated or asked at any point in the dialog and how it gets stated or asked. So the ice-breaking dialog to start each VPSP session differs for our 4 year old female character from our 9 year old male character.
- Emotional/social. We track a set of emotional states for each virtual human, separating personality (stable values) from mood (dynamic values). Emotional states are updated based on analysis of the user's input. For instance, a shy or scared young child in the clinic will become more compliant (say, for having ears checked with a virtual otoscope, as is required in our VPSP scenario with a girl) given a personalized request from the participant rather than a formal command. Similarly, part of anger management that at-risk teens are taught involves seeking information, verbalizing feelings or intentions or needs, and compromising and negotiating; our virtual teenager must realize when the participant is following these guidelines.
- Linguistic/gestural. Not only do the virtual humans interpret user input, they also generate appropriate responses, such as replies, challenges, denials, and zone outs. Along with verbal responses come informative gestures of the head, arms and hands, and whole body. Gestures, eye gazes, and posture follow the pragmatics of conversation, as understood by the particular virtual character. Our virtual teenager remains in one position (the environment is a school hallway) because the entire interaction is based on conversation. Similarly, our virtual boy remains on an examination room bed but allows the user to move from front to back to check lungs and airways with a virtual stethoscope. In contrast, our virtual girl moves among a play table, bed, and her mother's lap in the examination room, depending on her emotional state, the mother's suggestions, and input from the user.
- Physiological. In some RVH applications we use a multiple-compartment transport architecture that represents physiological functions and pharmacological actions and interactions. The physiology model centers around a cardiovascular model with compartments for the brain, heart, and liver. A blood transport model conveys numerous materials (gases, inhaled agents, drugs, chemicals and chemical agents, ions, hormones, and tracers) into and out of compartments.

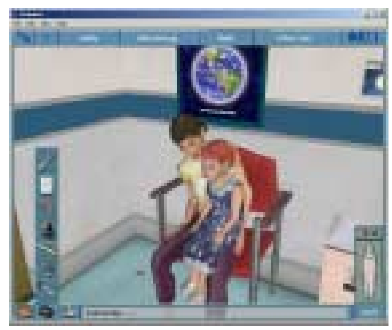
Since a child's mental and physical characteristics differ from an adult's, we've adapted existing behavior models and 3D character representations to enable the virtual children to express a wide range of realistic emotions and body movements. For the VPSP, we've also created a virtual clinical environment in which the user's actions strongly influence the child's behavior. We have gathered modeling data through videotaping of medical students and pediatricians interacting with kids and of kids in natural settings, direct observation, discussions with subject matter experts, motion capture (to generate credible body movement animations), and what literature exists on children's behavior.

3. Results

Screenshots are shown below for the two applications. The virtual teenage vignettes are being used as part of study of neurocognitive-emotive process deficits that may contribute to differential responses to preventive interventions. The vignettes were developed to assess adolescents' social/cognitive skills, emotional control, and decision-making ability. We've observed participants (inner-city at-risk male teenagers) to readily suspend disbelief (a common measure of the integrity of VR applications), but we've yet to formally determine if the simulation is realistic enough to gauge efficacy of intervention. VPSP is under development to be integrated and assessed in a pediatrics rotation. Similar RVH applications to VPSP have been evaluated and their usability assessed, with users feeling the simulation is easy to use, useful, highly meaningful for training and practice, and likely to continue to be used [4]. Continuing formal studies are underway.


Virtual teenager


Pre-teen boy on examining table


Young girl with mother

4. Novelty/Discussion

In prior work the University of Colorado School of Medicine developed CD/web delivered case simulations of pediatric patients using a problem-based learning strategy (the Learning through Interactive Video Education project) to evaluate a student's history taking skills from a parent and pediatric clinical recognition skills [5]. We are building on our experience in creating scenarios for VPSP and have added a second virtual character (a parent) to the scene. Both the teenage vignettes and the VPSP work build upon parallel RVH training applications done by RTI, such as a Trauma Patient Simulator [6] and a trainer for police officers to manage encounters with mentally disturbed individuals [7]. The novelty for us as developers has been in modeling children's behaviors, an area of RVH that to date has received scant attention (save for character behavior in some games that is still not all that flexible or elaborate). The novelty for participants is in interacting with responsive virtual characters, an engaging experience that might prove sufficient for assessing the participants' behavior.

We aim to continue to expand RVH technology to improve pediatric behavior models. For instance, we expect to extend the physiology model to apply to young, pre-teen, and teenage children. Also, we will improve our speech recognition and NL processing. Also, we are researching how to obtain user information based on voice data, facial expression, and maybe even heart rate, galvanic skin response, or other non-invasive measures.

5. Conclusions

Role-plays have their purpose in training and assessment but have limitations (e.g., reliance on prepared scripts, time required for setup and conduct, student observers in passive learning mode). SP programs are realistic and beneficial but also have known limitations (e.g., actor training and time is expensive, student throughput is limited, and variations in patient age, gender, and ethnicity are not easily accommodated). Moreover, child actors cannot be expected to provide reliable pediatric patient conditions.

To overcome some of these limitations, we have developed two RVH applications using pediatric virtual characters. Based on earlier RVH work and preliminary findings, we believe a VPSP can represent a realistic, reliable, and valid clinical assessment of pediatric history taking, PE, diagnosis and management, and communication skills. We are also encouraged by preliminary results from virtual teenage vignettes developed to assess adolescents' demonstration or avoidance of risky behavior.

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