A Virtual Patient to Assess Pediatric Intensive Care Unit (PICU) Nurses' Pain Assessment and Intervention Practices

Sangyoon Lee[1], Cynthia M. LaFond[2], Andrew E. Johnson[1], Catherine Vincent[2], Jason Leigh[1], and Luc Renambot[1]

[1] Dept. of Computer Science, University of Illinois at Chicago, IL, USA
{slee14,ajohnson,spiff,renambot}@uic.edu
[2] College of Nursing, University of Illinois at Chicago, IL, USA
{clafon2,vincentc}@uic.edu

Abstract. Pediatric intensive care (PICU) nurses play a crucial role in managing children's pain. While virtual patient (VP) technology has shown significant benefits in assisting with the practice of healthcare, there has been little research effort in this particular setting. This paper presents a pilot evaluation study to determine the validity of VP vignettes - including PICU nurses' recognition of the facial expressions (smiling and grimacing) of VPs and nurses' descriptions as to whether the VP vignettes are consistent with their professional experiences. The results of our initial study (n=20) confirm that nurses identified given expressions correctly (98.5%) and validated the similarity of the vignettes to their experiences with patients in the PICU (87%). A better understanding of nurses' pain management practices will aid the development of future VP interventions.

Keywords: Virtual Patient Vignette, Pain Assessment, Intervention Practice, Pediatric.

1 Introduction

The use of a virtual patient (VP) in healthcare and clinical settings has been actively studied. VPs provide robust tools for training medical professionals [1,2] and for examining how patient profiles influence pain assessment [3,4]. This is especially true [5,6] when the VP is deployed in conjunction with a traditional written vignette that provides a medical context in which to study disparities in nurses' pain-related decision making. VPs enhance written vignettes by providing a consistent stimulus from which nurses respond, likely improving the uniformity of data [7]. Furthermore, variables (such as facial actions) among VPs can be more carefully controlled than video among actual patients or actors, especially in the case of school-age children, as fraudulent pain expressions are easily detected in this age group [8]. Additional criticism of the written vignette includes its simplicity and decreased demand for interpretation of information [7]. To better simulate nurses' workflows and usual visual methods of

R. Aylett et al. (Eds.): IVA 2013, LNAI 8108, pp. 159–167, 2013.

obtaining patient information, our work incorporated VPs as well as video and simulated patient electronic medical records to replace all written vignette information (e.g., vital signs, medication orders). These VP vignettes were piloted with pediatric intensive care units (PICU) nurses in a mixed-methods study to evaluate the effect of child behavior and pain type upon their pain assessment and intervention choices. Uncontrolled pain is the second most common adverse event in PICUs in the United States [9,10]. Nurses have a crucial role in managing children's pain; a better understanding of their pain management practices will aid the development of future VP interventions. However, to date VP efforts have been developed for nurses working with adults. Our study aims to validate the VP vignette with respect to children's pain assessment - including PICU nurses' recognition of specific facial expressions and descriptions of the vignettes consistency with their professional experiences. We will also discuss the feasibility of implementing a VP vignette within a hospital setting. The rest of this paper is organized as follows: Section 2 reviews studies related to our work; Section 3 describes the PICU vignette scenarios and the implementation details; Section 4 presents the user study, preliminary results, and a discussion; and, Section 5 presents our conclusions.

2 Related Work

Among the disciplines that can benefit from virtual human (VH) technology, healthcare and clinical settings have been widely studied; in fact, the use of VP models to train healthcare professionals is a popular topic in the literature. Mehra and Lee analyzed early examples of VHs in healthcare and illustrated the fundamental principles and the architecture behind VHs [11]. A more specific example of VP use is found in [1], a VP for clinical therapists. The study showed how VPs could help novice clinicians practice interviewing and diagnosing skills. Conversely, Pontier and Siddiqui presented a virtual therapist preferred by users responding to questionnaires about depression [12].

In the literature on emotional expression research, Ekman's classic study [13] has been extensively adopted to model human emotions in VHs. His Facial Action Coding System (FACS) and Action Units (AU) provide foundations to analyze facial muscle movement in the categorical emotions; the resulting empirical data can be used to develop more realistic emotions in VH interfaces. To this end, Hirsh et. al. used FACS to realize pain expressions in their VP models, used to evaluate disparities in pain assessments amongst patients with variations in sex (male or female), race (Caucasian or African-American), and age (young or old) [14]. They modeled the VH pain expressions with the following AUs: brow lowerer (AU4), cheek raiser (AU6), eyelid tightener (AU7), nose wrinkler (AU9), upper lip raiser (AU10), and eye closure (AU43). This systematic composition of facial expressions offers a more controlled uniform realization method for VPs. Our study relies on the same principles to implement the grimace expression; however, we also iteratively validated our model with a FACS certified expert and our study is specifically designed for children's pain assessment (10-years-old) within the PICU environment.

3 Virtual Patient Vignette

Our VP scenario is derived from the Pain Beliefs and Practices Questionnaire (PBPQ) case studies [15,16]. The written PBPQ cases present 10-year-old boys who had abdominal surgery a day before, have a self-assessed pain rating of 8 on a 0-10 numeric pain scale, and have stable vital signs. One boy smiles and jokes whereas the other grimaces. Nurses are asked to rate each child's pain from 0 to 10 and choose the analgesia dose they would provide (if any). Because of the subjective nature of pain and the child's verbalization of pain poorly relieved from a prior dose of morphine, the response considered most correct for these vignettes included an agreement with the child's pain rating of 8 and increasing the morphine dose (regardless of the child's facial expression or diagnosis). We adapted these scenarios for a VP vignette and included two additional patients experiencing pain from a sickle-cell vaso-occlusive crisis (one smiling, one grimacing). The adapted vignettes were reviewed by content experts, advanced practice nurses with expertise working with critically ill children.

Fig. 1. Virtual Patient Head Models

The LifeLike Responsive Avatar Framework (LRAF) [17] is used to realize a VP. First, we made 4 patient models from photos of 9-11 year-old boys to simulate the PBPQ scenario. Second, we designed facial expressions (smile and grimace) with a FACS certified expert. Last, the VP vignette application was implemented. We created a child model for the first time. All our previous VH designs were based on people with ages ranging from 20-60 years old. We were able to generate models that looked close enough to the target children via our design pipeline and a head generation method (Figure 1).

The grimace expression is based on FACS and observed facial movements, or FACS AU [18]. The initial set of AUs selected for the grimacing patient was brow lowerer (AU4), cheek raiser (AU6), nose wrinkler (AU9), and mouth stretcher (AU27). In addition, we applied dynamic facial wrinkles to the facial expressions. During our iterative review session with a FACS coder, she confirmed that the wrinkle feature enhanced the quality of the perceived expression. The smile expression is selected from one of LRAF's basic expression templates (open-smile) together with slight lip stretcher (AU20) and lips part (AU25). In the final configuration, we chose AU 4, 6, 7, 9, 20, and 25 with a wrinkle intensity 0.6 at

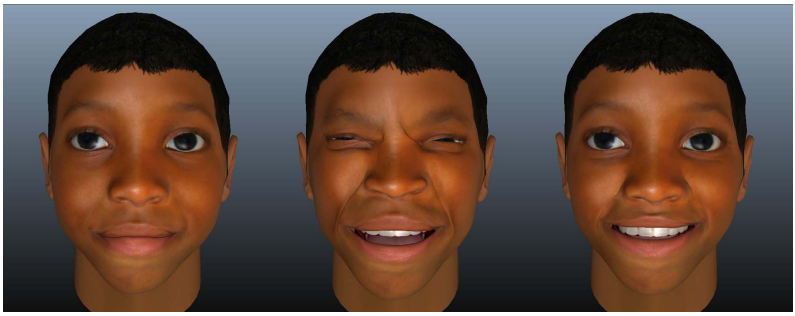

Fig. 2. Virtual Patient Facial Expression (left: neutral face; center: grimace; right: smile)

the peak of grimace animation (Figure 2. center) to achieve the desired facial expression. A wrinkle intensity is 0.7 is used for the smile expression (Figure 2. right).

Due to limited hardware accessibility on-site (hospitals), we implemented a web application with recorded videos (15 seconds each). Figure 3 illustrates the deployed application. In the main GUI, a subject can navigate menu buttons to see patient record information, VP animation, patient monitor (current vital signs), the medication administration record, and the patient's self-assessed pain level.

Fig. 3. Pain Vignette Application (left: main GUI; center: virtual patient; right: patient monitor)

4 Pilot Study

The goal of the study is to validate our VP vignettes with the PICU population. It includes PICU nurses' recognition of the intended facial expressions as well as their descriptions of the vignettes consistency with their professional experiences. We present preliminary results from a mixed-methods study in which PICU nurses' beliefs regarding children's pain and their simulated pain assessment and intervention practices were evaluated; of specific interest for the larger study was the effect of child behavior (smiling or grimacing), pain type (sickle cell vaso-occlusive crisis or abdominal surgery), and vignette type (written or virtual) upon the nurses' pain assessment and intervention choices.

4.1 Design and Procedure

For our VP vignettes, we replaced all written PBPQ vignette information with digital media, such as animated VPs, simulated vital signs, simulated electronic patient flow-sheets, and medication orders. Patient information and medication administration records were created to mimic computer screens that nurses use in their daily work. Vital signs were captured from a simulated patient monitor. It is a 30-second video clip showing stable vital signs with some mild variability in heart rate and oxygen saturation (BP: 102/60, HR: 80, R: 20, SpO2: 98%). The VP animation shows the bust of a child and zooms in to a close-up of his face. For the smiling vignette, the VP looks left, smiles, turns back to front, and smiles again. Smiling while looking left simulates joking with visitors (no audio or visitors' visual representations given). In the grimacing vignette, the VP illustrates the same head motion as the smiling VP whereas the grimacing VP only grimaces when turning his head forward. These movements were chosen to maintain consistency with the written PBPQ vignette descriptions of patients. Both VP videos have the same length, 15 seconds.

Procedure: Approval was obtained from the Institutional Review Boards. Once consent was obtained and a demographic questionnaire was completed, each subject was shown five vignettes with a different model (one practice model and four test models). At the end of each session, the subjects were asked to rate each child's pain (0-10) and to determine corresponding interventions. To avoid an order effect, the sequence of the test vignettes was randomly assigned. Semi-structured interviews followed the completion of all vignettes to elicit details regarding the subjects' choices. For each of the vignettes, nurses were asked what they were thinking about as they rated the child's pain and made a decision regarding pain intervention. After discussing all four vignettes, the PICU nurses were encouraged to share any additional information regarding assessing and intervening for children's pain. Finally, they were asked how consistent the vignettes were with their experience as a PICU nurse. Transcriptions of the interviews were analyzed using qualitative content analysis [19].

Participants: A convenience sample of nurses was recruited from PICUs at two hospitals in the Midwest, a large children's hospital and a university-based hospital. Of the first 20 PICU nurses to participate in the study, 85% were female, 70% identified their race as white, 20% Asian, 5% Black or African American, and 5% Hawaiian or Pacific Islander, and 5% identified their ethnic category as Hispanic or Latino. The nurses' years of PICU nursing experience ranged from 1-29 years, with a mean of 12.1 years (SD 9.2). All of the nurses described caring for children experiencing pain in the past 3 months, with the majority (60%) reporting to care for 1-5 children in pain each week. The remaining 40% reported caring for children in pain more frequently (30% 6-10 per week, 10% more than 15 per week).

4.2 Results and Discussion

We sought two measures: (1) did subjects correctly identify facial expressions presented; and, (2) did subjects find the vignette consistent with their professional

practice? Additionally, we sought to determine (3) how feasible is the use of VP vignettes as an instrument to elicit responses from nurses within the hospital setting?

Identification of Facial Expressions: The semi-structured interviews were analyzed to determine nurses' recognition of the intended facial expressions of the VPs. Though the nurses were not asked to identify the facial expressions of the VPs, many of them discussed the VPs' facial expressions while describing pain assessment and intervention choices. When facial expressions were described, the nurses identified a VP's intended facial expression 98.5% (64/65) of the time. When discussing the smiling patients, nurses used the word smile or smiling for 77.5% of the VP viewings (31/40); 10% (4/40) of the expressions were described with terms such as happy. For the remaining 12.5% (5/40), the patients' facial expression was not discussed some of these nurses reported that facial expressions were not an important aspect of their pain assessment. When discussing the two grimacing patients, 69% of the time (27/39 VP viewings) nurses used the words grimace or wince to describe the patients' facial expressions. Two times, nurses referred to the expression as showing pain and distressed. One nurse used the word smile while describing a patient with a grimace (1/39). However, it is unclear if this response was a misidentification of the facial expression or an inaccurate recollection of the patient being discussed.

Consistency of Vignette with Professional Practice: At the end of each interview, nurses were asked if the VP vignettes were consistent with their professional experience as a PICU nurse. Eighty-seven percent of the nurses (15/18, two audio recordings were interrupted) validated the similarity of the vignettes to their experiences with patients in the PICU. Comments provided included *"I've seen patients like this before," "I didn't see anything here I haven't seen a million times already," and "It's good. It exemplifies real life as far as what you see with our patients."* The remaining three nurses (17%) did not specifically confirm consistency of the vignettes, but instead elaborated on their personal experiences with patients in pain. Though the majority of nurses confirmed the vignette's accurate depiction of patients, some discrepancies were identified with the medication order (30%), and the lack of vital sign changes with pain (25%).

Feasibility

(a) Time and expense: Differences in the facial structures of the boys in the photos led to inconsistencies in the intensity and presence of some of the AUs, requiring additional manipulation of each VP to achieve equivalence. Additionally, some of the predefined AUs did not incorporate the response of other areas of the face to the movement of the action unit. This was especially problematic for the lower face leading to the need to engage additional action units to accomplish the originally intended AU. The use of a FACS coder is essential if realistic expressions are desired, especially in the case of a research study in which findings rely upon the participants' response to the expressions. These additional steps and the involvement of a consultant add to the expense and the time until completion of a VP vignette.

(b) Practicality: As previously mentioned, web-based vignettes allowed for flexibility in the locations in which subjects could meet the principal investigator. All 20 of the nurses in this study preferred to meet the principal investigator before or after their shifts at the hospital where they worked. The only required equipment was a laptop; however, we chose to use a 24-inch LCD monitor so that the nurses could better view the vignettes and a wireless mouse to ease their navigation.

(c) Usability: As previously mentioned, the nurses were introduced to a practice vignette prior to viewing and responding to the study vignettes. All of the nurses became proficient with navigating the practice vignette in a short amount of time (roughly 3-5 minutes) and completed viewing all four test vignettes, rating the VP pain level and documenting interventions, in generally 20 minutes or less.

5 Conclusion and Future Wrok

In this research, we designed a VP vignette for PICU nurses' pain assessment based on PBPQ case studies. The written PBPQ scenario was automated using VP animations, videos of vital signs, and images of patient information and medication orders. We created a VP that targeted school-age children and looked close enough to convey PBPQ scenarios. The VP vignettes were easily ported to multiple study sites and the PICU nurses were able to quickly navigate and assimilate the information within the vignettes. The main barriers to developing the VP vignettes were the need for a certified FACS coder and the multiple revisions required to achieve the desired expressions.

Pilot study results suggested that nurses identified given expressions correctly and validated the similarity of the vignettes to their experiences with patients in the PICU. The nurses' request for more information regarding the patients, including the ability to further assess the patients' pain, supports their engagement in the vignettes, and speaks to the potential usefulness of interactive VP vignettes for future research and training. We are currently completing data collection and plan to further analyze data to compare the use of a VP to elicit responses from PICU nurses' regarding their pain assessment and intervention practices to the classical written method.

Acknowledgments. This publication is based in part on work supported by the National Science Foundation (NSF), awards CNS-0420477 and CNS-0703916. This work was also partially supported by Seth and Denise Rosen Memorial Research award, The International Nursing Association for Clinical Simulation and Learning Debra Spunt award, Sigma Theta Tau Alpha Lamba Research award, and University of Illinois at Chicago College of Nursing Student Research award. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the funding institution.

References

1. Kenny, P., Parsons, T.D., Gratch, J., Leuski, A., Rizzo, A.A.: Virtual Patients for Clinical Therapist Skills Training. In: Pelachaud, C., Martin, J.-C., André, E., Chollet, G., Karpouzis, K., Pelé, D. (eds.) IVA 2007. LNCS (LNAI), vol. 4722, pp. 197–210. Springer, Heidelberg (2007)
2. Rossen, B., Cendan, J., Lok, B.: Using Virtual Humans to Bootstrap the Creation of Other Virtual Humans. In: Allbeck, J., Badler, N., Bickmore, T., Pelachaud, C., Safonova, A. (eds.) IVA 2010. LNCS, vol. 6356, pp. 392–398. Springer, Heidelberg (2010)
3. Stutts, L.A., Hirsh, A.T., George, S.Z., Robinson, M.E.: Investigating patient characteristics on pain assessment using virtual human technology. European Journal of Pain 14(10), 1040–1045 (2010)
4. Wandner, L.D., Stutts, L.A., Alqudah, A.F., Craggs, J.G., Scipio, C.D., Hirsh, A.T., Robinson, M.E.: Virtual human technology: patient demographics and healthcare training fac-tors in pain observation and treatment recommendations. Journal of Pain Research 3, 241–247 (2010)
5. Hirsh, A.T., George, S.Z., Robinson, M.E.: Pain assessment and treatment disparities: a virtual human technology investigation. Pain 143(1), 106–113 (2009)
6. Hirsh, A.T., Dillworth, T.M., Ehde, D.M., Jensen, M.P.: Sex differences in pain and psychological functioning in persons with limb loss. Journal of Pain 11(1), 79–86 (2010)
7. Hughes, R., Huby, M.: The application of vignettes in social and nursing research. Journal of Advanced Nursing 37(4), 382–386 (2002)
8. Larochette, A., Chambers, C.T., Craig, K.D.: Genuine, suppressed and faked facial ex-pressions of pain in children. Pain 126(1), 64–71 (2006)
9. Agarwal, S., Classen, D., Larsen, G., Tofil, N.M., Hayes, L.W., Sullivan, J.E., Storgion, S.A., Coopes, B.J., Craig, V., Jaderlund, C., Bisarya, H., Parast, L., Sharek, P.: Prevalence of ad-verse events in pediatric intensive care units in the United States. Pediatric Critical Care Medicine 11(5), 568–578 (2010)
10. Larsen, G.Y., Donaldson, A.E., Parker, H.B., Grant, M.J.C.: Preventable harm occur-ring to critically ill children. Pediatric Critical Care Medicine 8(4), 331–336 (2007)
11. Mehra, V., Lee, W.S.: Virtual humans in healthcare. In: Proceedings of the 3rd IEEE International Workshop on Haptic, Audio and Visual Environments and Their Applications (2004)
12. Pontier, M., Siddiqui, G.F.: A Virtual Therapist That Responds Empathically to Your Answers. In: Prendinger, H., Lester, J.C., Ishizuka, M. (eds.) IVA 2008. LNCS (LNAI), vol. 5208, pp. 417–425. Springer, Heidelberg (2008)
13. Ekman, P., Friesen, W.: Facial Action Coding System: A Technique for the Measure-ment of Facial Movement. Consulting Psychologists Press, Palo Alto (1978)
14. Hirsh, A., Alqudah, A.F., Stutts, L.A., Robinson, M.E.: Virtual human technology: Capturing sex, race, and age influences in individual pain decision policies. Pain (2008)
15. Manworren, R.C.B.: Development and Testing of the Pediatric Nurses Knowledge and Attitudes Survey Regarding Pain. Pediatric Nursing 27(2), 151–158 (2001)
16. Vincent, C., Wilkie, D.J., Wang, E.: Pediatric Nurses Beliefs and Pain Management Practices: An Intervention Pilot. Western Journal of Nursing Research 33(6), 825–845 (2010)

17. Lee, S., Carlson, G., Jones, S., Johnson, A., Leigh, J., Renambot, L.: Designing an Expressive Avatar of a Real Person. In: Allbeck, J., Badler, N., Bickmore, T., Pelachaud, C., Safonova, A. (eds.) IVA 2010. LNCS, vol. 6356, pp. 64–76. Springer, Heidelberg (2010)
18. Wilkie, D.J.: Facial Expressions of Pain in Lung Cancer, Analgesia, vol. 1, pp. 91–99 (1995)
19. Hsieh, H.F., Shannon, S.E.: Three Approaches to Qualitative Content Analysis. Qualitative Health Research 15(9), 1277–1288 (2005)