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Physical-Virtual Patient Bed

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1. Narrative

Introduction

Currently healthcare practitioners use patient simulators such as actors, mannequins, and computer based simulations for learning and training. Human actors cannot portray certain medical conditions [1], and sometimes they are hard to recruit (e.g. infants, children). Mannequins have a static appearance and could not provide dynamic visuals cues (e.g. facial expressions, skin color) [2]. Computer-based simulators are typically rendered on a flat screen limiting the touch stimuli a participant could receive from the patient. Healthcare educators try to compensate for the lack of the simulator's capabilities by providing verbal "hints" or by using hybrid simulations (e.g. combine a mannequin and a computer screen) to compensate for the missing cues, but this can reduce the fidelity and realism of the simulation. High-fidelity human simulation might positively impact a high level of cognitive and clinical skills acquisition [3], has a potential to support and affect the development of clinical judgment [4]. More realism increases attention and retention [5]. The closer the realism is to clinical reality, the easier it is for participants to engage in the simulation scenario [6]. In 3D virtual environments, co-locating haptic cues with visuals cues greatly improves performance, and are linked to eliciting sense of presence [7,8].

I am exploring effects of co-locating sensory cues (i.e. visual and haptic) vs the separation of these cues during a patient simulation in terms of performance, perception of realism, and cognitive load. To do so, I designed and developed a prototype for a patient simulator that combines dynamic visual cues with haptic and auditory cues in one physical space where all those cues are co-located (integrated). This prototype is what I refer to as the Physical-Virtual Patient Bed (PVPB). In the section below I describe the prototype I built for a child simulator with a study planned to use it (Fall 2017), a prototype for an interactive Physical-Virtual Head (PV-Head) with a study we are currently (Summer 2017) running to assess the touch accuracy on the PVHead, and a "stroke study" that I ran during Spring 2017 using the PVHead.

Results

This section covers the development of the PVPB prototype, a planned experiment using PVPB, enhancements for touch interaction on a PVHead (a subset of the PVPB), and an experiment that we ran using the PVHead.

PVPB Prototype Development

I designed and put together a mobile prototype for the PVPB which includes building a mobile rig that supports multiple projectors, infrared cameras, infrared lights, speakers, tactile units (for pulse), and temperature units. The dynamic imagery is projected on a removable shell [Fig 1]. I designed a 3D patient shell to allow for subtle movement such as head rotations and hands animations [Fig2]. After searching for and testing different plastic materials with different optical properties, I found a material that allows for projection and touch sensing at the same time. I sent the 3D files to a local manufacturer to create the shell [Fig3]. I also explored creating simulated soft skin on top of the shell so the simulator feels closer to a real human skin [Fig 12-13]. I created the 3D model of a child, textured and rigged it to

match reference material provided by experts. The 3D child supports facial expressions [Fig 15], speech [Fig 14], and body animations. I can easily change the medical state of the child to match the simulation scenarios (healthy patient, sepsis patient, burn patient, child with signs of abuse…etc) [Fig 4-11].

PVPB Planned Experiment

I am currently collaborating with faculty form college of nursing and from college of medicine regarding the medical content for the experiment. This experiment is planned for Fall 2017 where we manipulate the sensory cues in terms of fidelity, spatial location, and integration with each other (i.e. visual cues and physical form). Nurse Practitioners are asked to assess the patient during a simulation. One group interacts with the PVPB while another group interacts with a mannequin and monitor. We are planning to compare the participants' perception of realism, cognitive load, and performance between both conditions. We will also repeat the experiment with professional nurses at a local hospital.

PVHead Development and Current Touch Study

In addition to working on the development of the PVPB (software, hardware, and experiments), together with another PhD student we focused on improve the development pipeline and performance of the interactive reaction to touch using the Physical-Virtual Patient Head (PVHead) [Fig 16]. The PVHead is a subset of the PVPB that consists of a 3D Model of a head with blend-shape animations for facial expressions. The PVHead is rear projected on a plastic shell that has a matching physical form. When the head is touched, the position of the touch is computed and sent to the graphics engine. The graphics engine determines which animation should be triggered and updated based on the touch position on the shell. The same technology applied to the PVHead can be used on the PVPB for the coming Fall 2017 experiment. We are currently running a study to compare the touch accuracy with a physical shell vs a flat shell, and to compare projected graphics vs. augmented graphics (using a HoloLens). We are also comparing the usability and the cognitive load of participants depending on the physical form of the shell, and on how the graphics is displayed (projection vs HoloLens).

Stroke Study using the PVHead

In collaboration with faculty from College of Nursing, I ran a study with nursing students to assess realism, and learning. Participants were asked to assess the patient (as neurological assessment for a patient that has stroke) [Fig 17]. Participants were randomly split into a control group interacting with a Mannequin, and an experimental group interacting with the PVHead and a mannequin's body. Preliminary result are in favor for the PVHead in terms of knowledge retention, and perception of realism (full results are not published yet).
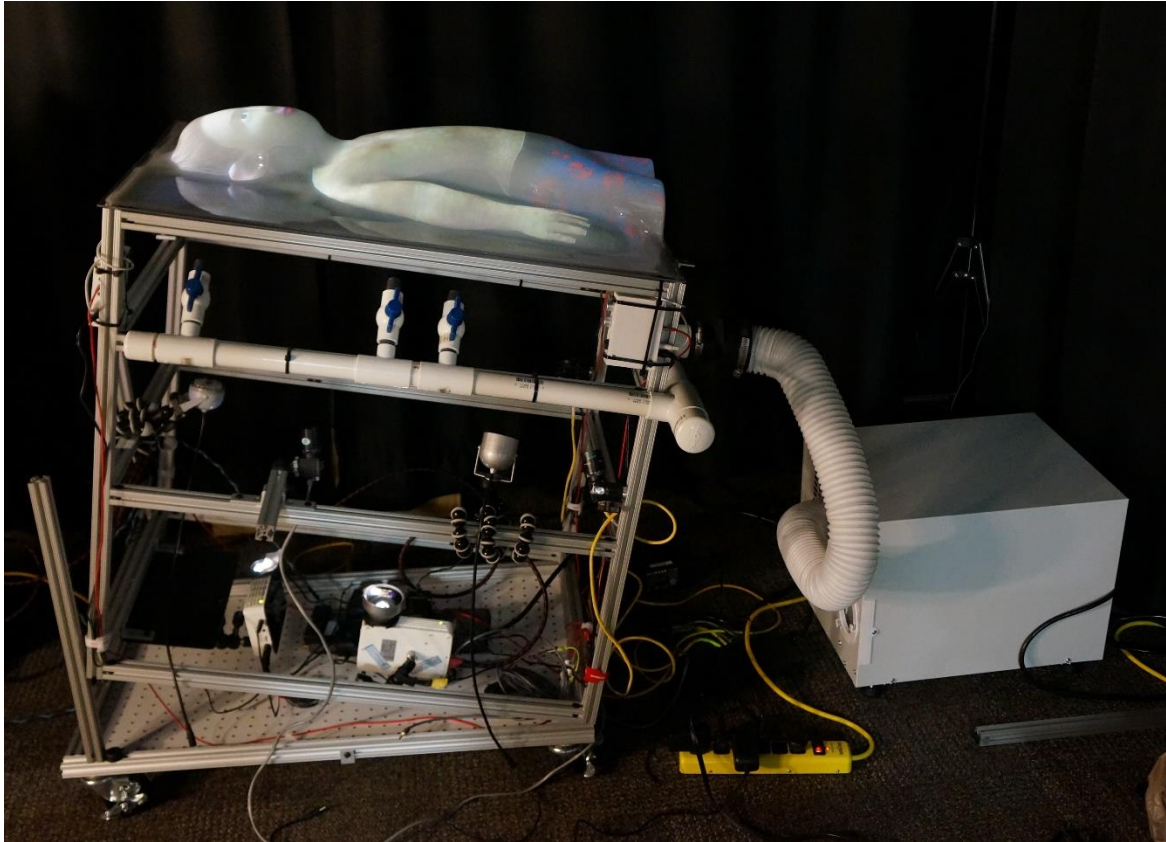
Fig1: Hardware for the PVPB showing a mobile rig, 2 projectors, 2 infrared lights, 3 cameras, 4 haptic feedback units, an air condition unit with pipes, and a shell on top.
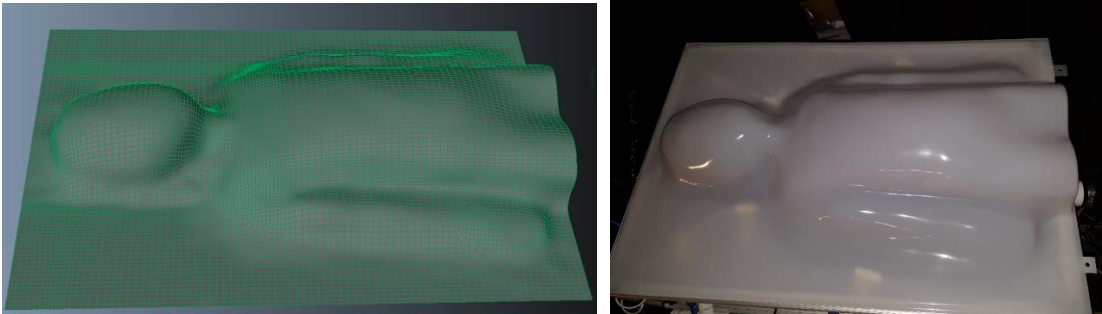

Fig 2-3: To the left, image of the 3D file used for creating a mold to vacuum form a plastic shell. To the right, image of the vacuum formed plastic shell. The shell is used to project imagery on it.
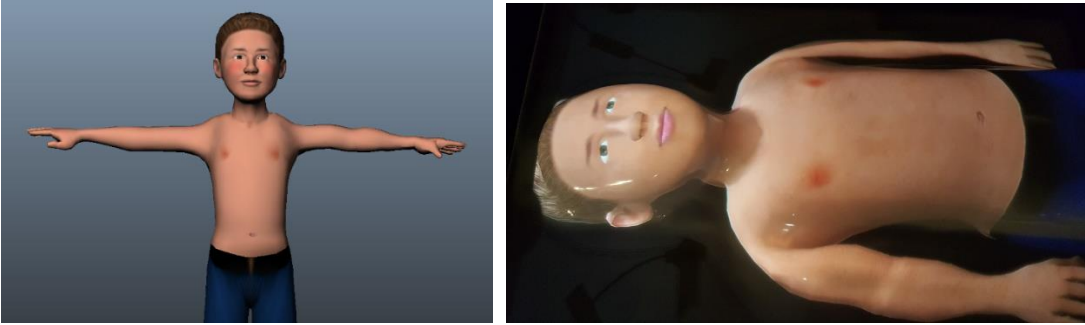
Fig 4-5: To the left, 3D model of a healthy patient rendered on a flat screen. To the right, the imagery of a healthy patient is rear-projected on the shell.
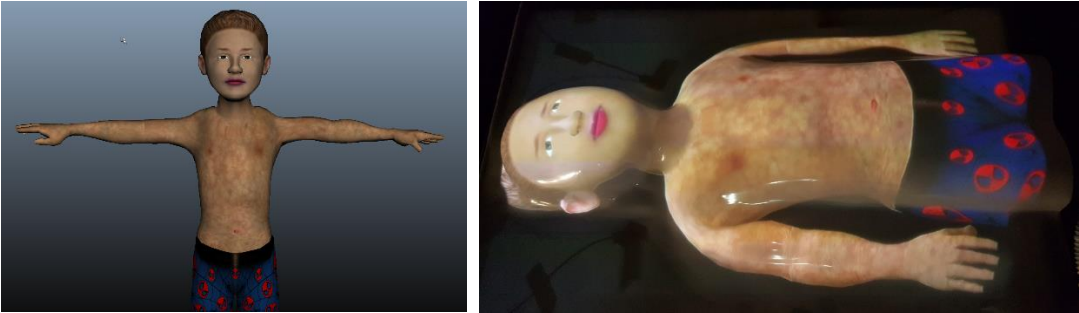

Fig 6-7: To the left, 3D model of a sepsis patient rendered on a flat screen. To the right, the imagery of a sepsis patient is rear-projected on the shell.
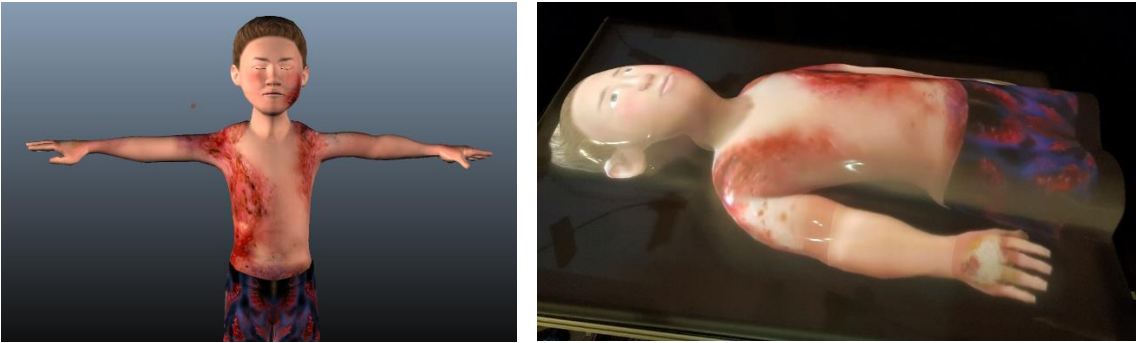

Fig 8-9: to the left, 3D model of a burn patient rendered on a flat screen. To the right, the imagery of a burn patient is rear-projected on the shell.
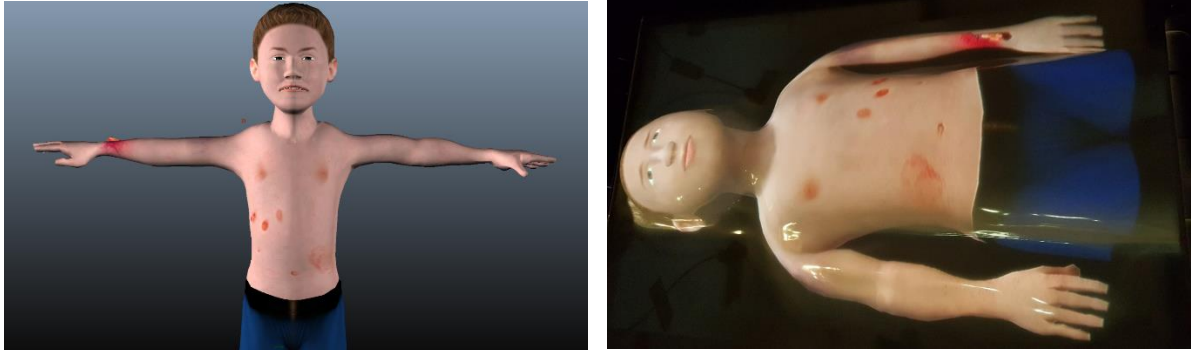
Fig 10-11: to the left, 3D model of a patient with signs of child abuse rendered on a flat screen. To the right, the imagery of a patient with signs of child abuse is rear-projected on the shell.
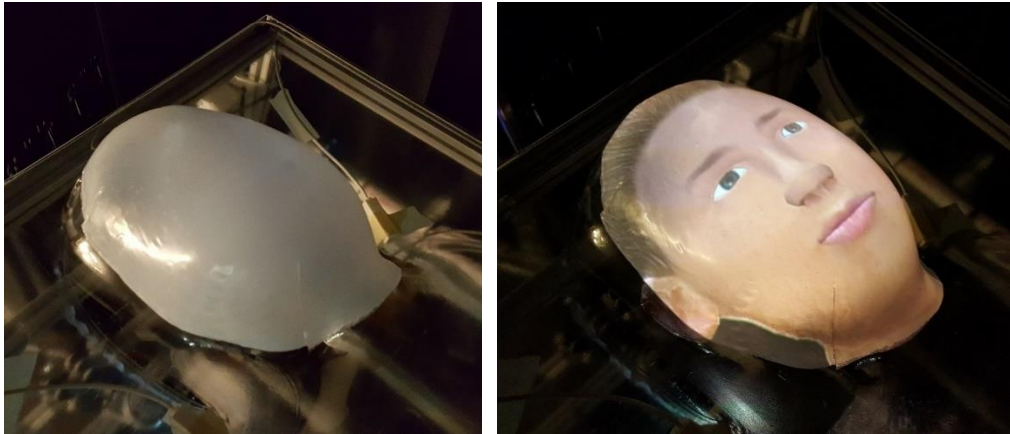

Fig 12-13: The image to the left shows simulated skin on a transparent plastic shell without imagery. The image to the right shows imagery projected on the simulated skin.

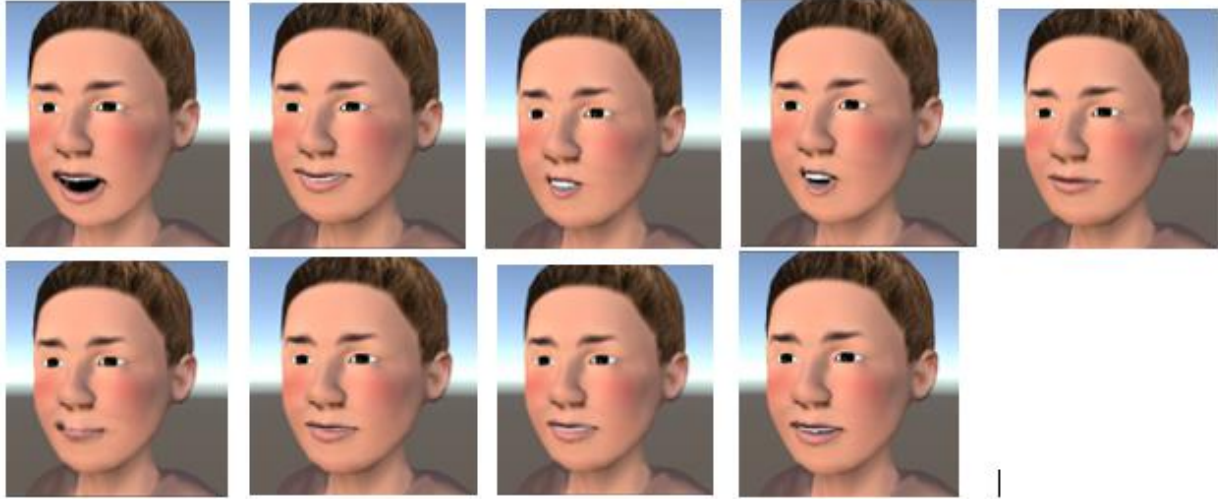Fig 14: This series of images shows visemes applies to the character to make the character capable of speech and lip-sync.

Fig 15: This series of images shows different facial expressions. Each facial expression represents one or more facial muscle groups (Action Units from the Facial Action Coding System). The intensity of each Action Unit can be changed, also multiple action units can be combined to create more facial expressions.
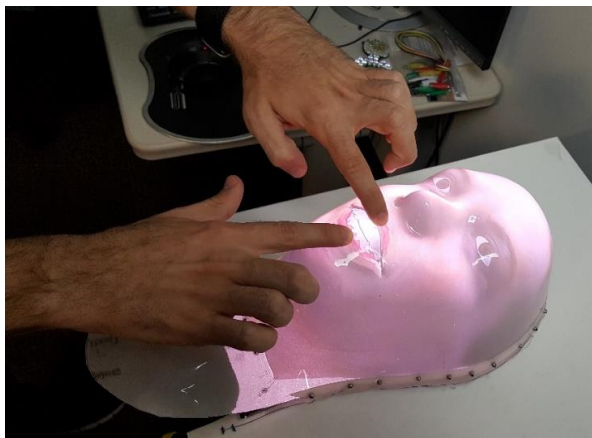
Fig 16: This image shows the PVHead with multiple touch interactions after we improved the accuracy. The same technology can be applied to the PVPB.

Fig17: This photo shows a nurse using the PVHead during a study. The imagery on the head shows a patient with a stroke highlighting facial drooping, slurred speech, slow pupil response to light, and different response to touch between right and left side of the patient.

Significance and impact

Adding high fidelity visual cues to existing simulators can be an affordable and an accessible way for educators and trainers to improve the outcomes of their patient simulations which could increase learning outcomes, improve patient safety, and reduce medical errors. While the results of the "Stroke Study" are not yet published, I have evidence that participants who interacted with the PVHead show higher retention, and expressed higher sense of realism during the scenario compared to those who interacted with the mannequin. After the study, the instructor of the class asked if she can use the PVHead for future classes.

Where might this lead?

Co-locating (integrating / registering) visual cues to physical form may push educators and the simulation industry into exploring novel approaches for combining these cues, allowing for a wider range of cues representation, therefore simulation of a wider variety of medical conditions that are currently hard to represent. In turn, using higher fidelity simulators with a wider range of scenarios could contribute to better learning outcomes.

2. How did the fellowship make a difference?

The Link Fellowship allowed me to work full time on a project that interests me, therefore accelerated the progress towards my dissertation. Since then I passed my candidacy exam, and my proposal was approved by my committee for conducting further studies. This fellowship also allowed me to collaborate further with researchers from different disciplines (college of nursing, college of medicine, computer science & engineering), and with experts in the industry (plastic manufacturing, moulage experts) to develop the prototype, plan the research, and for conducting studies. I am very thankful and honored to be a Link Foundation Fellow.

3. Future Plans

I plan to conduct the planned experiment this year and to finish my dissertation. After I graduate I would like to continue working in the same field of research whether in the industry or in the academia.

4. Publications, Presentations, and Other Outputs.

I presented my work at the IEEE VR 2017 Doctoral Consortium. The position paper is published in the proceedings of the conference.

Presented / Published

[9] Salam Daher, Optical See-Through vs. Spatial Augmented Reality Simulators for Medical Applications". In: Proceedings of IEEE Virtual Reality 2017, Los Angeles, CA, USA, 2017

[10] Salam Daher, Kangsoo Kim, Myungho Lee, Gerd Bruder, Ryan Schubert, Jeremy Bailenson, Greg Welch. Effects of Social Priming on Social Presence with Intelligent Virtual Agents. In Intelligent Virtual Agents (IVA), 2017.

[11] Salam Daher, Kangsoo Kim, Myungho Lee, Gerd Bruder, Ryan Schubert, Jeremy Bailenson, Greg Welch. Can Social Presence be Contagious? Effects of Social Presence Priming on Interaction with Virtual Humans. In 3D User Interfaces (3DUI), 2017 IEEE Symposium, 2017.

Submitted (expected to be published in September)

[12] Salam Daher, Laura Gonzalez, Gerg Welch. "Physical Virtual Patient Head". Submitted to Florida Nurses Association. Expected to be published in September 2017.

Planning to Submit with acknowledgment to the Link Foundation.

- A paper to Society for Simulation in Healthcare (or similar venue) regarding the study involving the PVHead
- A paper to IEEE VR 2018 involving a study related to Touch accuracy on the PVHead.
- A paper after running the experiment with the PVPB in the Fall 2017. The venue is to be determined.

Other Outputs

I passed my candidacy exam and proposal which is a milestone towards finishing my PhD.

5. References

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[9] Salam Daher, Optical See-Through vs. Spatial Augmented Reality Simulators for Medical Applications". In: Proceedings of IEEE Virtual Reality 2017, Los Angeles, CA, USA, 2017

[10] Salam Daher, Kangsoo Kim, Myungho Lee, Gerd Bruder, Ryan Schubert, Jeremy Bailenson, Greg Welch. Effects of Social Priming on Social Presence with Intelligent Virtual Agents. In Intelligent Virtual Agents (IVA), 2017.

[11] Salam Daher, Kangsoo Kim, Myungho Lee, Gerd Bruder, Ryan Schubert, Jeremy Bailenson, Greg Welch. Can Social Presence be Contagious? Effects of Social Presence Priming on Interaction with Virtual Humans. In 3D User Interfaces (3DUI), 2017 IEEE Symposium, 2017.

[12] Salam Daher, Laura Gonzalez, Gerg Welch. "Physical Virtual Patient Head". Submitted to Florida Nurses Association. Expected to be published in September 2017.