Matching vs. Non-Matching Visuals and Shape for Embodied Virtual Healthcare Agents

Salam Daher*, Jason Hochreiter, Nahal Norouzi, Ryan Schubert,
Gerd Bruder, Laura Gonzalez, Mindi Anderson, Desiree Diaz, Juan Cendan, Greg Welch

University of Central Florida

ABSTRACT

Embodied virtual agents serving as patient simulators are widely used in medical training scenarios, ranging from physical patients to virtual patients presented via virtual and augmented reality technologies. Physical-virtual patients are a hybrid solution that combines the benefits of dynamic visuals integrated into a human-shaped physical form that can also present other cues, such as pulse, breathing sounds, and temperature. Sometimes in simulation the visuals and shape do not match. We carried out a human-participant study employing graduate nursing students in pediatric patient simulations comprising conditions associated with matching/non-matching of the visuals and shape.

Index Terms: Human-centered computing—Human computer interaction (HCI)— HCI design and evaluation methods—User studies; Human-centered computing—Human computer interaction (HCI)—Interaction paradigms—Mixed / augmented reality

1 INTRODUCTION

Augmented and mixed reality technologies have much potential in improving combined visual and physical training realism and thus the effectiveness of medical training. It is still an open question how to best incorporate dynamic visuals into simulations to elicit realistic perceptions, cognitive load, and behavior, and to foster natural responses in trainees. For instance, some researchers have supplemented static mannequins with videos and audio on a nearby screen [1], but this separated presentation of physical human form and dynamic visuals may reduce the effectiveness of the simulator. There is an inherent amount of mental and physical effort required when assessing a real human patient, as medical assessment involves multiple interactive elements such as listening, looking, and even touching. This effort, referred to as *cognitive load*, is bound by the limited capacity of the working memory. It is important to manage extraneous cognitive load so that learning is not adversely affected.

We are interested in researching how the matched or mismatched interaction between the physical shape and visuals of a simulated patient could affect overall cognitive load. Specifically, we considered whether the separation of dynamic visuals increases cognitive load due to the introduction of additional elements that might occupy more space in working memory and in comparing the cognitive load induced by a patient with a flat shape compared to a patient with a physical shape (similar to a real human). Simulators that require effort comparable to diagnosing real humans may require higher overall cognitive load than other simulators, but they are still valuable training tools and could potentially lead to better training outcomes. We conducted a human-participant study with nursing students to assess these effects using a physical-virtual patient simulator for pediatric medical training purposes based on two training scenarios.

*salam.daher@ucf.edu

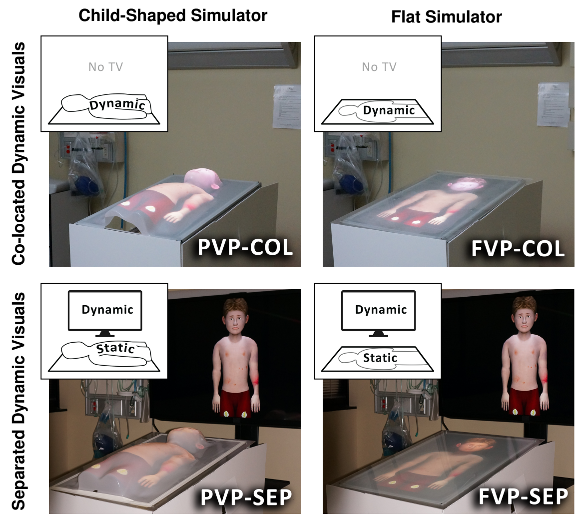

Figure 1: The four study conditions, which considered the presentation of dynamic visuals and the simulator shape.

Our research is guided by the following hypotheses regarding the location of dynamic visuals and the shape:

- H1 **Cognitive load scores** will be higher for assessment of a child-shaped simulator than for a flat one.
- H2 **Cognitive load scores** will be higher when dynamic visuals are separated from the physical patient.
- H3 When dynamic visuals are separated onto a TV, participants will consider the TV as **representing the patient**.

2 EXPERIMENT

2.1 Apparatus

We developed a pediatric *Physical-Virtual Patient* (PVP) simulator representing a 6-year-old child that can support integrated multisensory output including visuals, audio, and touch. The virtual aspects of the simulator consist of projecting animated imagery rendered using the Unity 3D graphics engine. We developed content for two medical scenarios (sepsis and child abuse). In this study, we examine the importance of the matching/non-matching of visuals and shape by comparing four variations of an embodied virtual agent for patient simulation (Fig. 1). These include the co-located presentation of all cues (COL conditions) or the separate presentation of dynamic visuals (facial expressions, movements) on a TV screen (SEP conditions). Next, to compare the effects of the shape of the patient simulator, we further developed a similar Flat-Virtual Patient (FVP) simulator, using the same equipment as the PVP but with a flat surface. Our study apparatus and software support all 4 experimental conditions:

- **PVP-COL**: Child-shaped shell with co-located dynamic visuals
- **FVP-COL**: Flat shell with co-located dynamic visuals
- **PVP-SEP**: Child-shaped shell with separated dynamic visuals on a TV
- **FVP-SEP**: Flat shell with separated dynamic visuals on a TV

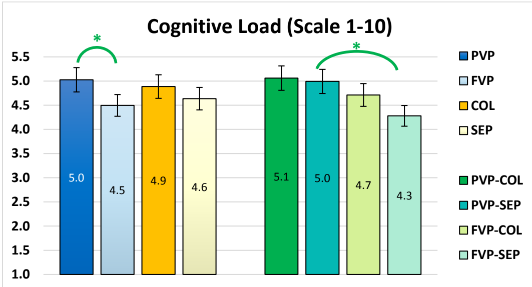

Figure 2: Cognitive load results (NASA-TLX).

2.2 Participants

We recruited 44 graduate nurse practitioner students to participate in our study. The simulation experiment was conducted as part of an advanced health assessment class in the local university's nursing program. Pairs of participants each assessed the two simulated patients in randomized and counterbalanced orders.

2.3 Study Design and Procedure

The study, approved by the Institutional Review Board, featured a mixed design, with both within- and between-participant components. All pairs of participants performed two simulated patient assessments: one with co-located dynamic visuals and one with separated dynamic visuals on a TV screen. The physical form of the PVP (child-shaped or flat) was consistent across these two assessments and was instead varied as a between-participant component.

First, each participant independently completed a pre-questionnaire concerning basic demographic information, vision issues, and prior exposure to simulated patients. Each pair watched a short video (approximately 3 minutes) featuring an abstract sample assessment of a healthy simulated patient corresponding to the next study condition, demonstrating its various capabilities. After the video, the pair was given the patient's history. The participants were instructed to assess the patient once the simulator operator gave a verbal "begin simulation" command. Participants had a total of approximately 10 minutes to complete their assessment, which ended when the operator gave a verbal "end simulation" command. Following each assessment, participants individually completed post-questionnaires relating to their experience (i.e., evaluation of the simulator and cognitive load).

2.4 Measures

Each participant completed the NASA TLX [2], which reflected the mental, physical, and temporal demands they experienced during their assessments in a series of Likert scale questions from 1–10. We also asked participants which of the two separated entities they thought represented the actual simulated patient.

3 Results

We used Mann-Whitney U for independent samples and Wilcoxon signed-rank for paired samples to analyze the Likert-scale ordinal data from the questionnaires.

3.1 Cognitive Load: Child-Shaped vs. Flat Simulator

Participants were more likely to have a higher cognitive load in the PVP conditions than in the FVP conditions (Fig. 2). The difference is significant ($U = 675$, $p = 0.014$), supporting our hypothesis H1. Similarly, the cognitive load was higher for the PVP-SEP compared to the FVP-SEP ($W = 139.5$, $p = 0.016$).

3.2 Cognitive Load: Co-location vs. Separation

We observed no significant overall differences between the COL and SEP conditions, which does not support our hypothesis H2 (Fig. 2). However, one of the NASA-TLX questions indicates that participants expended more mental and physical effort when assessing the COL conditions compared to the SEP conditions ($W = 314$, $p = 0.032$). For assessments of the FVP-COL compared to the FVP-SEP, we observed the same trend concerning increased effort ($W = 92.5$, $p = 0.060$) and a trend for another NASA-TLX question suggesting increased physical demand ($W = 53.5$, $p = 0.067$).

3.3 Patient Identity

After each SEP condition, participants were asked "In the case where you had both a simulator and a separate TV screen, which one seemed more like the patient you were treating?" Two participants did not answer the question. A trend shows that participants perceived the dynamic visuals as being the true patient instead of the physical simulator presenting the rest of the cues, $\chi^2(1, N = 42) = 3.4, p = 0.064$. For the PVP-SEP ($N = 21$), the answers were almost evenly split, with 10 participants feeling that the child-shaped simulator with static cues was the actual patient and 11 feeling that TV with dynamic imagery was. There is no statistical difference, which does not match our hypothesis H3 in this case. In contrast, participants in the FVP-SEP condition perceived the TV screen with dynamic visuals as being the patient more so than the the physical simulator with static visuals, temperature, and pulse on a flat surface, $\chi^2(1, N = 21) = 5.8, p = 0.016$, supporting our hypothesis H3 in this case.

4 Conclusion

In this paper, we presented a human-participant study concerning the matching of visual and shape characteristics of simulated patients. Our study considered two independent variables: the location of dynamic visuals (co-located with or separated from the physical simulator) and the physical shape of the simulator (human-shaped or flat). Pairs of graduate nursing students assessed two patients in the scope of an advanced health assessment class: one showing signs of child abuse and one with signs of sepsis.

For the child-shaped simulator, we observed greater cognitive load than for the flat simulator, suggesting a more realistic level of workload, characterized by the participants' behavior, e.g., moving their head around the three-dimensional patient to examine it from all sides. We also observed results suggesting that participants perceived the TV screen with dynamic visuals more as the locus of the patient they were assessing than the simulated patient with temperature and pulse lying in front of them. This effect was significant when the static simulator had a flat shape, while participants with the child-shaped simulator were equally split between whether they considered the physical simulator or the TV to be the patient.

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