The Augmented Anesthesia Machine, a Mixed Reality Application in Anesthesia

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INTRODUCTION

- The free, web-enabled Virtual Anesthesia Machine (VAM) simulation [1] employs transparent reality [2] to render the flow of gases in an anesthesia machine visible, through transparent pipes and tubes and color-coding gas molecules icons (Figure 1). Transparent reality, as used in VAM, has been shown to enhance understanding of anesthesia machine function compared to an otherwise identical photorealistic simulation [3].

- With prior IRB approval, undergraduate students with no prior knowledge of anesthesia machines were divided into 2 groups of 10. For each participant, the study took place over two days.

- However, a small subset of VAM users seems to be challenged in transferring the abstract knowledge acquired with the virtual VAM to an actual anesthesia machine. To facilitate knowledge transfer from the virtual to the physical world, we developed and evaluated the Augmented Anesthesia Machine (AAM). The AAM is a mixed simulation that uses a "magic lens" to overlay in real time a virtual, dynamic, transparent reality representation over a corresponding physical counterpart, e.g., a bellows, a bank of flow meters or the entire anesthesia machine.

OBJECTIVES

- Our objectives fell into two broad categories:
  (a) implementation of an AAM
  (b) evaluation of the resulting AAM in terms of learning outcomes

METHODS

- Implementing the AAM. In the AAM, a tracked "magic lens" implemented via a lightweight tablet PC displays a scaled, high-resolution graphical model of the anesthesia machine model that is registered to the real machine [4,5].

- To track the position and orientation of the magic lens, we use a computer vision technique called outside-looking-in tracking (Figure 3). The technique employs stationary cameras that monitor markers attached to the tablet PC magic lens to calculate its 3D position and orientation. The magic lens has three retro-reflective markers (balls) attached to it. Each ball has a predefined position relative to the other two balls. Triangulating and matching the balls from at least two camera views allows calculation of the 3D position and orientation of the balls and thus of the magic lens.

- In the AAM, instead of using a mouse to interact with the virtual simulation, actual controls such as the nitrous oxide flow meter knob are adjusted by the user, providing for a realistic (tactile and haptic) interaction. To track the anesthesia machine configuration in the older Modulus II design (which had minimal electronic integration), we instrumented the desired controls and used a 2D optical tracking system with 4 webcams driven by OpenCV to monitor their states (Figure 2).

- In the Augmented Apollo anesthesia machine, we used the Drager Medibus communication protocol to track the state of the anesthesia machine in quasi-real time and obtained a more tidy and less obtrusive look by eliminating the 2D optical tracking system.

RESULTS

- There were no significant differences (p = 0.2144) between groups on the written tests. The mean VAM score was higher but not statistically significant [4].

- There were no significant differences in VAM-Icon-to-Machine mapping ability, participants were asked to match the simulation components (e.g. icons) in a screen shot of the training simulation (either VAM or AAM) to a picture of the real machine.

- Fault detection (missing inspiratory valve leaflet) was significantly higher (p=0.0176) with the AAM group (6/10) vs. the VAM group (1/10) [4].

- The AAM group took significantly longer (p = 0.002) than the VAM group to complete the 5 training exercises on the first day [4].

- There is no significant difference when applying traditional performance and spatial-layout intelligence tests [6].

- There is no significant difference in spatial-cognitive ability at three different scales: Arrow Span Test, Perspective Taking Test (intermediate scale), and Navigation of a Virtual Environment Test (large scale) [8].

- Large scale and better spatial abilities facilitated performance in the VAM users, but had minimal effects on AAM users' performance, suggesting the augmented simulation compensated for weak visualization skills [5].

DISCUSSION

- Misuse was three times more common than equipment failure in closed claims (most due to death and permanent brain damage) associated with gas delivery equipment [8]. Effective educational and training techniques such as the Augmented Anesthesia Machine may have the most potential to compensate for low spatial cognition, reduce human error and improve the safety of anesthesia equipment.

- The AAM has also been used for after action review (debriefing) [9].

REFERENCES


