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Virtual Role-Models: Using Virtual Humans to Train Best Communication Practices for Healthcare Teams

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Abstract. Due to logistical scheduling challenges, social training of conflict resolution skills with healthcare professionals is a difficult task. To overcome these challenges, we used virtual humans to fill in as surgical teammates and train conflict resolution skills in a surgical scenario. Surgical technologists were recruited at a United States teaching hospital to interact with a virtual nurse, virtual surgeon, and virtual anesthesiologist in a team training exercise. Leveraging social learning theory, the virtual nurse on the team modeled one of two conflict resolution strategies, either best practices or bad practices, during an important decision moment in the exercise. In a second important decision moment, we assessed if surgical technologists demonstrated the conflict resolution model they observed. We found human participants were successfully able to demonstrate the ideal conflict resolution strategy after observing the virtual nurse model best practices. While we found participants were positively influenced by the best practices model, we also found that conversely, the bad practices model negatively influenced participants' conflict resolution behavior. If humans can be positively influenced by virtual humans, this form of social training could transform medical team training, empowering more healthcare professionals to speak up, and potentially decreasing the chances of patient morbidity or death in the OR.

Keywords: Virtual Humans, Social Learning Theory, Team Training

1 Introduction

Fig. 1. Surgical technologist conducting a closing count with a virtual team

Our paper explores how to use social training with virtual humans to teach best practices for communication in a medical team. Specifically, we investigate if humans are malleable and can be influenced to learn by example from virtual humans. If humans can be positively influenced by virtual humans, this form of social training could transform medical team training, empower more healthcare professionals to speak up to their team when they have concerns, and potentially decrease the chances of patient morbidity or death in the operating room.

To investigate this, surgical technologists were recruited at a United States teaching hospital to interact with virtual humans in a four-person surgical team training exercise. The training was intended to address one of the most important and difficult skills in the operating room: communication. At this hospital, nursing management implemented a policy requiring best communication practices during the closing count of a surgery. Best practices means speaking up if proper procedure is not followed and calling a supervisor or charge nurse if the issues cannot be resolved between the team. Failure to follow best practices during the closing count could lead to retained foreign bodies, i.e. surgical equipment left inside the patient. Retained foreign bodies can be harmful to patients and can cause severe injury or even death [1].

In perioperative care, role models are a valuable resource for ensuring a safe work environment and for ensuring patient safety [2]. Unfortunately, role models who exhibit best practices are not always present in the operating room. Research has shown that interpersonal conflict or bullying of staff is common especially with new hires with less experience [3]. One way to address the lack of positive role modeling is through social training.

Social training opportunities for healthcare teams; however, are difficult to coordinate [4]. Healthcare professionals have inflexible schedules and each member is essential in real operating room environments. To address these issues, we used virtual humans to fill in as operating room teammates and train best practices for conflict resolution in the operating room.

Leveraging social learning theory, a virtual nurse on the team modeled best practices for conflict resolution with a virtual surgeon during an important decision moment. We investigated if surgical technologists, after observing the first decision moment, would demonstrate a similar behavior in the same scenario during a subsequent closing count in which the virtual surgeon wants to make a risky decision.

We found human participants were successfully able to demonstrate the best practices for conflict resolution after observing the virtual nurse model best practices. While

we found human participants were positively influenced by the virtual nurse, we also found when the virtual nurse modeled bad practices for conflict resolution, surgical technologists were less likely to resolve the conflict effectively, e.g., call a supervisor.

2 Background

Our research leverages existing research on social learning theory and mixed reality virtual humans. With mixed reality virtual humans, we developed a medical team training scenario that incorporates social learning theory to enhance the training experience.

2.1 Social Learning Theory

Social Learning Theory was created by Albert Bandura who suggested learning is a social activity in which people can learn by observing the behaviors of others, also known as vicarious learning [5]. Bandura's most famous experiment, the Bobo doll experiment, demonstrated that children, when observing adults either play roughly or gently with a toy, the bobo doll, would imitate the behavior they observed when playing with the toy [6].

2.2 Virtual Humans

Virtual humans can be represented in many ways [7, 8]; however, for the purposes of our research, we used mixed reality agents known as ANDI [9]. These mixed reality humans are rendered life-size on a 40" television set in portrait mode. A Microsoft Kinect is used for head-tracking to enable head-gaze and perspective correct rendering.

The virtual humans interacted with human participants using pre-recorded dialog and motion-captured gestures and animations. The virtual humans used a simple eye-gaze model in which they looked at whomever was speaking and would intermittently glance at other teammates.

The virtual humans were operated using a Wizard-Of-Oz (WoZ) approach. In a WoZ system, a human operator listens to user input and controls the virtual human's dialog choices based on the user's input. We chose a WoZ approach to eliminate speech recognition and understanding errors as these errors could have interfered with the learning objects of the training exercise.

3 Related Work

This research builds on prior work applying social learning theory with virtual humans or agents.

3.1 Virtual Agents and Social Learning Theory

Social Learning Theory has been applied with virtual humans mainly in areas related to health, and bicycle safety.

Fox and Bailenson investigated how virtual representations of the self, also known as doppelgangers, could be used to influence exercise behavior [10]. In one study, participants saw the weight of a virtual representation of themselves fluctuate based on the participants' current physical activity. Participants who saw their virtual doppelganger lose/gain weight based on their activity performed more voluntary exercise than participants who saw an unchanging virtual doppelganger or no doppelganger.

Babu et al. developed a bicycle safety virtual environment in which children rode a bike with a virtual peer [11]. Participants interacted with either a risky virtual peer or safe virtual peer while crossing busy intersections in a virtual environment. A risky virtual peer crossed intersections with tight gaps between cars while a safe virtual peer chose large gaps between cars. Researchers found that participants who interacted with the risky virtual peer were negatively influenced by the risky peer's road-crossing behavior.

4 Virtual Human Training Exercise

4.1 Background

The virtual human training exercise used in this study was created in collaboration with nursing management at a teaching hospital in the United States. Nursing management indicated nurses needed to be trained on a policy change involving the closing count of a surgery. The closing count occurs prior to closing the surgical wound on a patient. The surgical team counts surgical items to verify they match the count conducted prior to the start of the surgical procedure. A new policy was put into place to ensure maximal patient safety when there is a discrepancy between the closing count and the initial count. When a discrepancy occurs, the surgical team should first try to locate the missing item. The process includes searching trash bins, sponge counting bags, drapes, and other places around the operating room. If the item cannot be located, an x-ray must be requested for the patient. Proper protocol states the attending surgeon on the team must speak with an attending radiologist to for review of the x-ray.

Nursing management believed employees at their hospital should feel empowered to speak up if proper protocol was not followed. To address this need, we created a scenario in which a virtual surgeon does not want to comply with the new closing count protocol after a discrepancy is discovered. For trainees, their goal was to speak up to the virtual surgeon, try to get the surgeon to follow the policy, and ultimately call a supervisor or charge nurse if the surgeon does not comply with the policy.

4.2 Virtual Humans

For this simulation exercise, we developed three virtual humans who formed an operating room team with the surgical technologist participant. In addition to the surgical team, a patient, in the form of a plastic mannequin patient simulator was also incorporated into the exercise. Doctor Girard is a new surgical attending who was recently employed at the hospital. Doctor Sanders is a new attending anesthesiologist. Sandy is a circulating nurse who works at the hospital. Depending on condition, Sandy either

modeled best practices of speaking up behavior for participants to learn. Eric Mason is 59 year old man who is undergoing a laparoscopic Whipple, or, pancreas removal. Eric was represented as a mannequin lying on an OR bed. To enhance realism, a monitor looped vital signs displaying his heart rate and other important vital information. An anesthesia machine was also cycling to simulate ventilation of the patient.

4.3 Scenario

The speaking up opportunities occur in two important stages of the surgical procedure. Each stage included an important decision making moment. The two stages are as follows: Pre-Incision Timeout and the Closing Count.

Prior to the two decision making moments, the participants interact with their virtual teammates in preparing the patient for surgery. This stage is known as the Pre-Induction Briefing. Participants and virtual humans introduce themselves to each other and the team works together to go over the patient's vital signs and information about the surgical procedure.

Pre-Incision Timeout – Decision Moment One. The Pre-Incision Timeout occurs right before the surgical procedure begins. During the timeout, anesthesia has already been induced, and the patient is prepped and draped for surgery. The Pre-Incision Timeout serves as a moment for everyone on the team to address any concerns and make sure everyone is on the same page before beginning the surgery. The decision moment is based on a prior need from nursing management. A similar decision moment was used in a prior study [12]

The virtual surgeon asks if there are blood products ready for the procedure. Due to some communication failures with the blood bank, the anesthesiologist admits blood is not currently available for the patient. The surgeon, frustrated with this information, berates the anesthesiologist for his mistake.

Because of the surgeon's heavy case load for the day, he makes the decision to continue with the surgery despite no availability of blood products in the room. At this point, the virtual nurse, Sandy, will either model the best or bad practices speaking up behavior. The details of these models are discussed later in Section 5.

Fig. 3. Setup of the Closing Count stage (from participant perspective) Nurse is on the left, surgeon in the middle, and anesthesiologist to the right.

Closing Count – Decision Moment Two. During the Closing Count stage, the surgical technologist and virtual nurse must work together to count all of the items prior to closing the patient. Surgical technologists were instructed to conduct the closing count as they normally would in a real operating room environment. The virtual nurse holds a clipboard of the initial count and verifies the number of items counted with what is on the initial count.

The Closing Count stage occurs after the surgery has been performed. To enhance the realism of the simulation, participants counted real surgical equipment. The equipment included items such as sponges, needles, and blades. The setup of the Closing Count stage can be seen in Figure 3.

While conducting the count, the virtual nurse and surgical technologist discover one item is missing. The item was intentionally missing for the purposes of the training; however, participants were not aware of this intention. The surgeon instructs the team to look for the missing item. After a few minutes of searching, the team concludes an x-ray must be obtained. An x-ray is displayed on monitors above the simulation area. After receiving the x-ray, the surgeon determines that the x-ray is clear (i.e., there is no foreign body present in the patient). Because to him, the x-ray is clear, the surgeon makes the risky decision to start closing the patient's incision. His decision puts the patient's life at risk, and violates hospital's policy which requires the attending surgeon to speak with the attending radiologist to clear the x-ray. This moment is the second speaking up opportunity in which we assessed the effect of the modeling.

5 Study Design

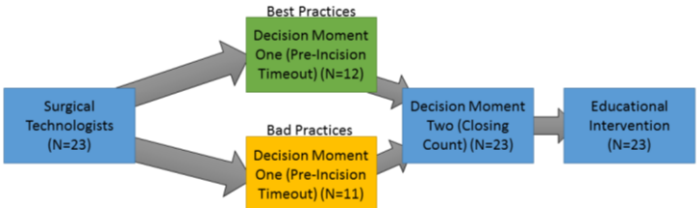

Fig. 4. Study Flow

The goal of this study was to investigate how to use social training with virtual humans to teach best practices for communication. While the main focus of this research is on teaching best practices for communication, we also investigated the effects of a virtual human modeling bad practices for communication. Unfortunately, the reality is healthcare professionals perceive that conflict resolution is not handled effectively in the OR [13]. The bad practices model was added to reflect the more common perception of how conflict is resolved in the operating room.

Participants were recruited from a United States teaching hospital. The participants were operating room surgical technologists at the hospital. Participants signed up for the training exercise through the hospital's training management system. 23 surgical

technologists were recruited for the study (19 female, 4 male). No participant had participated in a virtual human training exercise prior to attending this training.

5.1 Social Learning Component

Leveraging social learning theory, we developed a model of both best practices and bad practices speaking up behavior.

Best Practices Speaking Up. In the best practices model, the virtual nurse models ideal speaking up behavior as recommended by the hospital and literature. During Decision Moment One, the nurse objects to the virtual surgeon proceeding with incision. The virtual surgeon rebuts to every challenge the virtual nurse gives. The nurse challenges the surgeon six times before calling a supervisor to intervene in the conflict: "If you insist on proceeding, then I'm going to have to call my charge nurse." The surgeon responds: "Fine, you do that."

Bad Practices Speaking Up. In the bad practices model, the virtual nurses fails to fully model ideal speaking up behavior. During Decision Moment One, the nurse challenges the surgeon only four times. The four challenges are exactly the same as the first four challenges of the Best Practices model. After challenging the surgeon four times, the virtual nurse gives into the surgeon: "Alright, well… I think this is a bad idea, but (sigh) you're the surgeon, and it's your call." The surgeon responds: "Finally, thank you. Now let's keep going."

5.2 Procedure

With the exception of the speaking up model, the training exercise was identical for both groups of participants. First, participants interacted with the virtual team in Decision Moment One. Participants either observed a virtual nurse demonstrate a best practices or bad practices model of speaking up behavior. After Decision Moment One, the simulation is set up for the closing count stage. Approximately ten minutes elapse between Decision Moment One and when participants conduct the closing count which encompasses Decision Moment Two.

After completing the training exercise, we conducted an educational intervention for all participants. During the intervention, all participants watched a short video in which a surgeon employed at the hospital went over the importance of the new closing count policy. This surgeon helped draft the new policy.

In addition to viewing the video, we also gave participants a handout of the TeamSTEPPS protocol. The handout addressed effective speaking up strategies when dealing with conflict. These strategies include the two-challenge rule in which participants were told they should voice their concerns at least twice to ensure they've been heard. The other strategy was the "CUS" acronym. "CUS" are three important words participants can use whenever speaking up. These words are "Concerned", "Uncomfortable", and "Patient Safety".

6 Results

Results presented are based on the speaking up outcomes from Decision Moment Two of the training scenario. Specifically, we assessed whether or not the surgical technologist called a supervisor or charge nurse to intervene. While 23 surgical technologists were recruited, only 22 data points are considered. One participant in the bad practices modeling group called the charge nurse on her own during Decision Moment One which meant the participant did not see any form of modeling from the virtual nurse. Based on interviews with participants, most surgical technologists would not speak up about issues with blood products as, typically, issues with blood are not their responsibility. To analyze the results, we ran a 2x2 contingency analysis using permutations.

6.1 Speaking Up Outcomes (n=22)

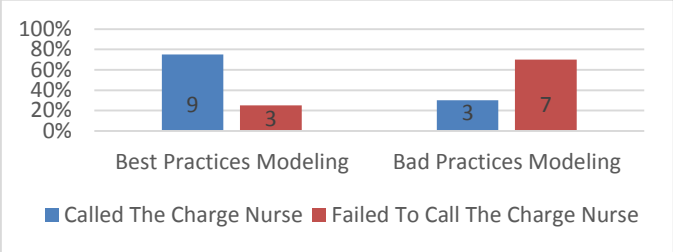

Fig. 5. Speaking Up Outcomes during Decision Moment Two

As seen in Figure 5, when participants observed the virtual nurse call the charge nurse in Decision Moment One, 75 percent of participants in Decision Moment Two called the charge nurse after the surgeon refused to comply with the hospital's closing count policy. When participants observed the virtual nurse back down to the surgeon in Decision Moment One, only 30 percent of participants in the Closing Count stage called the charge nurse. 70 percent of participants in the Bad Practices modeling group failed to call the charge nurse during Decision Moment Two. Only 25 percent of participants in the Best Practices modeling group failed to call the charge nurse during Decision Moment Two. The results are statistically significant with $p = 0.0304$.

7 Discussion

The results suggests participants were influenced by the model they observed. While the results are statistically significant, we also believe the results are practically significant given the participants for the study were healthcare professionals at an actual hospital. The participants work with real operating room teams on a daily basis caring for real patients. If virtual humans are capable of influencing how humans behave in a simulated environment, this same vicarious learning likely occurs in actual operating rooms. Unfortunately, in real high stakes environments, role models are not guaranteed

to be present. With virtual humans, we can guarantee everyone sees the same best practices model. The novelty of this research is how virtual humans can influence humans. Virtual humans can be used to teach real humans best communication practices that humans can potentially apply in real-world situations.

7.1 Ethics

The results present a potential ethical dilemma for future studies with virtual human behavioral modeling. Participants who observed the virtual nurse back down to the virtual surgeon in Decision Moment One may have received a subpar experience compared to the participants who observed the virtual nurse successfully speak up to the virtual surgeon. Most of the surgical technologists attended the training during work hours. They likely left a real operating room to attend training and went back to a real operating room immediately after the training. We do not fully know the extent to which the virtual nurse's behavior influenced participants; however, any potential negative learned behavior which could be carried over into a live operating room environment could impact patient safety. Despite seeing a virtual nurse model bad practices, all participants received the same intervention in which they were told the proper hospital policy and given a set of guidelines to speak up (TeamSTEPPS). We made sure that all participants left with something positive and encouraging

8 Limitations

There are two main limitations: a small sample size, and the possibility of priming.

Our sample, while small, is gathered from a population of healthcare professionals who work in very high stakes environments daily. Participants work with real teams in real operating room environments with real patients. Most participants worked with real patients on the same day they participated in the study.

Participants in the Best Practices modeling group may have been primed to call the charge nurse because they discovered it was a possibility of the simulation. The Bad Practices model participants did not see anyone call the charge nurse so they may not have realized calling the charge nurse was possible. We do not think any priming occurred. Participants in other conditions of the study (not relevant to the research presented in this paper) called the charge nurse at similar rates to the Best Practices modeling group without actually observing a virtual human call a charge nurse.

9 Conclusion and Future Work

Virtual humans are powerful tools for social training of effective communication strategies in a team training environment. If humans can be positively influenced by virtual humans, this form of social training could transform medical team training, empower more healthcare professionals to speak up, and potentially decrease the risk of

patient morbidity or death in the operating room. Our results show virtual humans can serve as role models; humans can learn from these virtual role models.

Anecdotally, for a five month period which coincided during and after the training, no retained foreign bodies were reported at the hospital. While we cannot claim causation, the decreased rate of adverse events is encouraging nonetheless.

Reflection is an important component of social training and was not addressed in this research. We believe that incorporating a reflective component in addition to the modeling component may improve outcomes for all participants.

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