FEATURE ARTICLE

Building a Handoff Communication Virtual Experience for Nursing Students Using Virtual Humans

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Effective communication among healthcare professionals is critical to delivering safe, high-quality patient care. One important real-world skill that nursing students must acquire is generating accurate handoff communication reports. The central aim of this study was to build, assess, and revise a virtual experience simulation that allows nursing students to observe a standardized clinical situation in an immersive environment and then practice the situation-background-assessment-recommendation communication method. This between-groups experimental study, which was modified in light of COVID-19 concerns, evaluated how well 69 prelicensure nursing students understood a handoff communication report after viewing a virtual human patient and nurse interact during a triage assessment scenario. Results indicate student comprehension levels did not differ based on which of two metacognitive learning strategies was used. Participants in both study groups were able to accurately complete a situation-background-assessment-recommendation instrument based on the virtual experience. Further, they believed that watching a virtual nurse perform a triage assessment would help them perform one themselves in a similar virtual environment. There was also an unexpected study finding related to patient safety within the context of the simulation. This finding warrants further research that will lead to revision of the virtual experience used to train future nurses.

KEY WORDS: Handoff communication, Nursing students, Virtual humans, Virtual reality

Effective communication of each patient's current medical status is an essential component of coordinated and reliable healthcare.[1,2] This includes patient reports exchanged between nurses at change-of-shift handoffs. Poor communication at such crucial junctures is associated with a higher risk of sentinel events.[1] Many nursing students have difficulty learning how to accurately communicate patient information in a clear and concise manner, a skill deficit that can adversely affect a student's clinical performance and self-confidence.[3] Factors that contribute to this learning struggle include student nurses' lack of experience, knowledge, and access to live patients for practice.[4] New pedagogically sound teaching methods that foster improved communication skills are clearly needed to continue improving nursing education for all students.[5]

Recent advances in computer technologies, specifically those associated with virtual experiences (VEs), are being used to improve nursing education and students' communication skills. VE is defined as a distinct, computer-generated reality that allows a single user or group of users to experience auditory and visual stimuli unique to a certain experience.[6] The current study focused on technological modalities used in education, including virtual reality (VR), augmented reality, online simulation modalities, and other avatar-based simulations.

As VE research in nursing education inevitably expands, one area in need of special attention is improving students' professional communication skills. These vital skills are needed when synthesizing patient information for a change-of-shift handoff using the situation-background-assessment-recommendation (SBAR) instrument.[7] SBAR is a standardized communication instrument used to pass report from one healthcare provider to the next in a variety of medical settings. This workplace process fosters a team-oriented healthcare approach centered on ongoing patient well-being.[8] With its emphasis on relevant clinical information synthesized for ease of comprehension, SBAR is also useful when outside providers (including non-nurses) join the healthcare team to treat a particular patient.[9] Evidence indicates that regular use of this instrument among novice nursing students results in positive patient outcomes attributable to clear and concise medical communication.[10–12]

Overall, research indicates nursing students view VE positively if the training simulation is properly designed. However, a poorly designed virtual exercise could prove less effective than traditional in-person simulation approaches. To prevent this, the current study incorporated metacognitive strategies to strengthen the VE design. Metacognition is an individual's knowledge about his or her cognitions, the parameters that influence those cognitions, and the person's ability to control them.[13] Simply put, metacognition is "thinking about thinking."[14] Metacognitive processes allow learners to better understand how they met educational goals and how they

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can improve based on their previous academic experiences. In the current study, metacognitive strategies provided a solid intellectual foundation for studying the learning abilities of nursing students. Two methods of deploying these strategies were explored to determine which was a more effective avenue for clinical knowledge acquisition in a virtual setting.

Besides deficient simulation design, other problems that can complicate VR-based education include prohibitive costs, technology glitches, and physical side effects for students, such as visual asthenopia and motion sickness.[15] It can also be difficult to measure real-world clinical competency when training takes place in a virtual environment.[16] Liaw et al[17] reported that VR avatar quality in general needs improvement and that currently virtual simulations are not superior to live simulations in terms of teamwork and communication development. White et al[18] tested how effectively post-anesthesia care unit nurses communicated patient information with a virtual attending physician. The researchers found that the nurses did not consistently convey critical information, and most missed a fatal dosage error during the handoff communication.[18] This finding highlights the value of using technology when training healthcare professionals so that hopefully such mistakes will not be repeated in real life. A study by Yeh et al[19] focused on nursing students learning about the SBAR instrument via online simulation-based deliberate practice. Regular engagement with the program translated into improved reporting skills.[19] Finally, Hanson et al[20] found that nursing students felt more empowered to speak up about an unsafe practice in an actual medical setting after completing a VE communication assertiveness activity prior to their first clinical placement.

Venkatesh and Bala[21] posited that, for individuals to accept an informational technology system, their experience using the system is vital—how users perceive the ease of use and perceived usefulness of the system. This third iteration of the technology acceptance model suggests that interventions be geared to the effective utilization of the informational technology, such as pre- and post-implementation strategies of design, image, relevance, output quality, computer self-efficacy, and perceived enjoyment. Authors proposed that, if users have more hands-on experiences with the technology, their acceptance to the technological system would be greater. The nursing students in this study receive two iterations of the handoff communication, and a realistic design and image of the avatar is shown.

Taken together, the above research highlights the value of virtual simulations in transferring acquired knowledge to the clinical setting. This is especially important for nursing students who lack real-world experience and confidence. With VE, they can practice—and learn by their mistakes—without fear of harming an actual patient.

THEORETICAL FRAMEWORK

This study used a dual theoretical framework of self-care deficit and investment theory. Focused on the importance of particular actions, the self-care deficit theory has been found to generate a distinct style of thinking and communicating, which is commensurate to the nursing profession.[22] Orem proposed that human beings require constant, reiterative inputs, which is part of natural life. Based on these constant and repetitive inputs, through human agency, people then have the power to act deliberately, to improve, or to care for themselves and others. Self-care theory has been the groundwork for several health-related practice studies.[23] Orem's self-care theory comprises four interrelated theories: theory of self-care, theory of dependent care, theory of self-care deficit, and theory of nursing systems.[22] The theory of systems is related to interpersonal relationship between the nurse and the patient receiving the care. Orem describes it as an action system, where a sequence of actions is performed for a purpose. This relates to the handoff report given in a systematic format using the SBAR communication instrument.

Investment theory as developed by Hatcher et al[24] addresses behavior associated with college students' satisfaction with educational experiences. Hatcher et al posit students are satisfied when they perceive a positive return on their investment of academic time, energy, and effort.[24] Other research indicates that high levels of student trust positively influence educational satisfaction.[25–27] The current study examined BSN students' satisfaction with and trust of a VE simulation designed to improve their SBAR skills. The goal is to use their feedback to improve the VE in the future to help increase the real-world abilities and confidence of nurses in training.

METHODS

This was a between-groups, pre-test/post-test experimental study. Participants were randomly assigned to the metacognitive question group or the metacognitive prompt group. Participants in the metacognitive question group received thought-provoking free-response style questions before viewing the nursing simulation video, directly after viewing the video, and at the end of the learning experience (see Table 1, items 11–13). Use of these questions corresponded to the planning, monitoring, and reflection phases in metacognitive learning. Participants in the metacognitive prompt group received a prompt, created by the University of North Carolina–Chapel Hill Learning Center, before watching the virtual nursing simulation. These prompts detailed metacognitive learning strategies, which the participants were then asked to utilize on their own.[28] An example of a question used for the metacognitive prompt group was "What strategies did you need to perform to properly fill out an SBAR tool?" An advantage to being a participant in the metacognitive prompt group was having a scripted guide

Table 1. Survey Items With Correct Answers

Items	Percentage Correct (Question Group/Prompt Group)
Pre/post-test questions	
1. What are the priorities of the triage assessment nurse? Select all that apply.	1. Airway with c-spine precautions Pre: 100%/100.00% Post: 92.8%/89.5% 2. Disability and resource management Pre: 31.9%/31.6% Post: 23.2%/23.7% 3. Medication reconciliation Pre: 4.4%/2.6% Post: 14.5%/10.5%
2. What is included in a primary survey of a triage assessment?	Pre: 31.6%/29% Post: 23.7%/32.3%
3. Please indicate whether the following statement is true or false. The situation in an SBAR report includes identification of self, department, and patient.	Pre: 94.7%/93.6% Post: 100%/96.8%
4. Please indicate whether the following statement is true or false. Pertinent information is included in the assessment section of an SBAR report.	Pre: 7.9%/16.1% Post: 5.3%/6.5%
5. What does the recommendation in an SBAR report include?	Pre: 92.1%/93.6% Post: 92.1%/96.8%
SBAR test questions	
6. This is an example of the situation section of the SBAR. Select all the information that is high priority for nurses to understand about the situation. Select all that apply.	1. 94.2%/97.4% (identify self: RN) 2. 97.4%/83.9% (identify department: ED) 3. 100%/87.1% (identify patient: John Sanchez) 4. 84.2%/71% (how injuries occurred: car accident) 5. 65.8%/71% (injuries occurred within 1 h of arrival to ED) 6. 68.4%/83.9% (severity of problem: multiple injuries)
7. This is an example of the background section of the SBAR. Select all the information that is high priority for nurses to mention about the patient background. Select all that apply.	1. 69.6%/79% (admitting diagnosis: multiple injuries from a car accident) 2. 50%/42% (vital signs: BP, 150/90; HR, 115; RR, 24; T, 98.7 °F) 3. 92.8%/92.1% (current meds: none) 4. 91.3%/92.1% (allergies: NKDA)
8. This is an example of the assessment section of the SBAR. Select the top 3 highest priority items below.	1. 34.2%/54.9% (seat belt injury: bruising from the left to right chest area) 2. 92.8%/92.1% (right lower abdominal laceration: bleeding from the right lower quadrant of the abdomen) 3. 94.2%/94.7% (open fracture of the right tibia: bone projecting from the skin on the right lower leg) 4. 18.8%/21.1% (observed multiple injuries) 5. 94.7%/80.7% (patient is complaining of severe chest, abdominal, and right lower leg pain, rating as a 10 on a 0–10 pain scale)
9. This is an example of the recommendation section of the SBAR. Select the Highest priority item below.	Immediate evaluation of patients' injuries is needed. 42.1%/54.8%
10. Select the second highest priority item below.	Patient needs pain medication for severe pain. 42.1%/51.6%
Metacognitive questions	
11. Planning question: Describe (1) what kind of information is necessary for an SBAR tool and (2) what strategies that you need to perform to properly fill out an SBAR tool.	Free response
12. Monitoring question: Please describe below what you believe the task you are about to have to complete will involve? Do you believe that you understand the task?	Free response
13. Reflection question: Describe below what strategies you believed worked and did not work, and what you may do differently next time to better complete the task.	Free response

(continues)

Table 1. Survey Items With Correct Answers, Continued

Items	Percentage Correct (Question Group/Prompt Group)
Trust questions	7-point scale of strongly disagree to strongly agree
14. Overall, the virtual nurse is a capable and proficient healthcare provider.	(0.0%, 0.0%, 2.9%, 17.4%, 15.9%, 50.7%, 13%)
15. The virtual nurse performs its role of performing medical procedures/protocols very well.	(0.0%, 0.0%, 0.0%, 14.5%, 23.2%, 50.7%, 11.6%)
16. I would feel comfortable acting on the medical information given to me by the virtual nurse.	(1.5%, 1.5%, 5.8%, 15.9%, 26.1%, 36.2%, 13%)
17. If I had a challenging medical problem, I would want to use the virtual nurse again.	(5.8%, 4.4%, 14.5%, 14.5%, 23.2%, 27.5%, 10.1%)
Student perception questions	
18. I believe watching the virtual nurse perform triage would help me to do this myself on a virtual patient.	7-point scale of strongly disagree to strongly agree (5.8%, 1.5%, 5.8%, 18.8%, 11.6%, 44.9%, 11.6%)
19. How could the virtual simulation be improved to help you perform triage on a virtual patient in a later simulation?	Free response

Alternative item answers were excluded in this table.

Abbreviations: BP, blood pressure; ED, emergency department; HR, heart rate; NKDA, no known drug allergies; RR, respiratory rate; T, temperature.

to answer the metacognitive questions instead of creating their own questions. Another advantage to having metacognitive prompt questions was the decrease in the amount of time needed to participate in the simulation. However, a disadvantage was the lack of free response in creating independent metacognitive questions.

PARTICIPANTS

This study enrolled 69 participants. All were senior BSN students enrolled in an advanced medical-surgical nursing offered at the College of Nursing at the University of Florida. Inclusion criteria included any senior nursing student enrolled at the university. Institutional review board approval was obtained before the study began. Because no personal health information was obtained, this project was deemed exempt by the institutional review board and considered a normal course activity. Students were recruited through an announcement posted within the nursing course's learning management system. If students wished to participate, they clicked on a secure online link, reviewed the informed consent form, and then enrolled electronically in the study. If students had concerns or questions about participating due to the accessibility in using the virtual resources, they were provided the researchers' contact information. Strict confidentiality was maintained throughout the study.

DATA COLLECTION

Measures/Description of Instruments

Instruments used to measure the teaching effectiveness of the simulation included a pre-test/post-test questionnaire that assessed students' SBAR and nursing triage knowledge. A five-item pre-test/post-test questionnaire was used to measure student SBAR and triage knowledge. Specifically, it assessed whether watching a virtual nurse perform triage on a virtual patient improved students' understanding of the triage and handoff processes. These questionnaire items were in multiple-choice or multiple-answer multiple-choice formats (see Table 1, items 1–5). In addition, an SBAR instrument was adapted for an online format. The SBAR instrument consisted of multiple-choice and multiple-answer multiple-choice items. These items measured students' prioritization skills, as well as their SBAR knowledge about a triaged virtual human patient (see Table 1, items 6–10).

Other instruments evaluated metacognitive strategies, trust levels, and participant impressions of the virtual learning experience. For the metacognitive strategy items, our independent variable was the delivery method of metacognitive strategies. One participant group was introduced to validated metacognitive strategies and told to use them as they saw fit.[28] The second group received three additional open-ended items (see Table 1, items 11–13). The intent of these items was to improve problem-solving performance by having students focus on the planning, monitoring, and reflection phases in metacognitive learning. These items were adapted from King,[29] who examined how training in strategic questioning impacts problem-solving performance. To assess participant trust level of the virtual human in the VE, trust-related items were adapted from the work of McKnight et al[30] (see Table 1, items 14–17). We measured both trusting beliefs and trusting intentions.[30] All items were rated on a 7-point Likert scale, with participant responses ranging from strongly disagree to strongly agree. To evaluate participant impressions of the virtual learning experience, feedback was elicited via a Likert scale and an open-ended study question.

Students were asked to comment on their virtual learning experience, including any criticisms they might have (see Table 1, items 18 and 19).

Case Scenario Development

Computer science faculty and doctoral students and nursing faculty from the University of Florida collaborated over the course of many months to construct the VE scenario used in this study. The time commitment for the study and any costs incurred were part of the university's commitment to research. The case scenario was an expected content area in the advanced medical-surgical nursing course of the curriculum. The computer science faculty and doctoral students had prior knowledge and experience in designing and implementing simulation, and the seasoned nursing faculty teaching in the advanced medical-surgical nursing course served as content experts for the emergency content. The senior nursing students had experience in using virtual simulation with prior use of online educational resources. The study simulation was developed using the Unity game engine, with characters developed using Adobe Fuse. Adobe MotionBuilder was used to create character animation. The virtual nurse voice was generated with Nvidia WaveGlow and Google's Tacotron2. The virtual patient audio was recorded by voice actors and edited using Audacity. Before the students watched the VE simulation, they were informed about four key matters: (1) the goal of the scenario (to virtually triage a patient and convey the nursing assessment in an SBAR report); (2) the structure and purpose of SBAR communication; (3) the participant role as observer in the scenario; and (4) the virtual setting and circumstances of the case scenario.

The scenario portrayed a 21-year-old male brought into the emergency department after a motor vehicle accident. The patient was moved to the triage area where the virtual nurse avatar performed the physical assessment, determining that the patient had sustained multiple injuries and was in severe pain. Prior to viewing the clinical simulation, study participants completed an SBAR communication pre-test. The participants had prior knowledge and experience in using SBAR as handoff communication in the areas of situation, background, assessment, and recommendation. After viewing the clinical simulation, study participants completed an SBAR communication post-test that the researchers used to assess their learning experience. In this study, the participants were assessed on their ability to apply their SBAR communication knowledge (see Figure 1).

COVID-19 Adaptation

The VE simulation was originally designed as a VR experience where nursing students would use head-mounted displays in an in-person academic setting. The goal was to compare the value of different simulated learning modalities. Due to COVID-19, however, the VE simulation had to be shifted to an online format of desktop using a 360 image for the environment (see Figure 2). Computer science and nursing faculty brainstormed to determine the most efficient way to switch technology to the online format. The end result was recording the simulation inside of Unity on a screen and sending it to students via the Qualtrics survey platform. However, it should be noted that this necessary study modification likely reduced the original immersion quality of the simulation.

RESULTS

Evaluation of Metacognitive Strategies

No significant differences were found on either the triage knowledge test or SBAR performance between the metacognitive prompt group and the metacognitive question group (see Table 2). The median time for participants to complete the VE was 14 minutes, with an average time to complete of 17 minutes.

Trust Evaluation

Participants were asked four questions to measure how much they trusted their virtual learning experience (see Table 1, items 14–17). Item 14, "Overall, the virtual nurse is a capable and proficient healthcare provider," and item 15, "The virtual nurse performs its role of performing medical procedures/protocols very well," measured participant trust in the competency of the virtual nurse (see Table 1, items 14 and 15). For item 14, 79.7% agreed to some degree that the virtual nurse was a competent healthcare provider, 17.4% neither agreed nor disagreed with the statement, and 2.9% slightly disagreed. For item 15, 85.5% of participants agreed to some degree, 14.5% neither agreed nor disagreed, and no one disagreed on any level. Item 16, "I would feel comfortable acting on the medical information given to me by the virtual nurse," and item 17, "If I had a challenging medical problem, I would want to use the virtual nurse again," measured the students' likelihood of trusting the clinical assessment of the virtual nurse. For item 16, 75.4% of participants agreed on some level, 15.9% neither agreed nor disagreed, and 8.7% disagreed on some level. For item 17, 60.9% of participants agreed on some level, 14.5% neither agreed nor disagreed, and 24.6% disagreed on some level.

Student Evaluation

The five-item pre-test/post-test questionnaire used to measure student SBAR and triage knowledge produced mixed results. Students performed well when indicating introductory skills such as what is included in the situation and recommendation sections of the SBAR (see Table 1, items 3 and 5) but struggled with selecting the priorities of a nurse during triage assessment, what is included in a triage assessment,

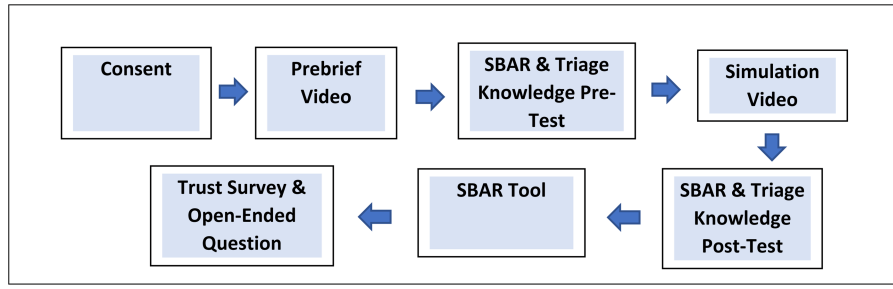

Figure 1. VE timeline.

and what is included in the assessment section of the SBAR (see Table 1, items 1, 2, and 4).

Students scored well on the SBAR-related multiple-answer multiple-choice items. The only instance where students did not select the correct choice greater than 75% of the time was when they did not select that the time injuries occurred before arrival to the emergency department in the situation section of the SBAR (see Table 1, answer 4 in item 6). Students struggled more to accurately answer the multiple-choice selecting the two highest priorities in the recommendation section, scoring below 60% on both items (see Table 1, items 9 and 10).

When participants were asked if watching the virtual nurse would help them perform a triage assessment on a virtual patient in the future, 68% replied affirmatively (see Figure 3). Evaluation of the participants' open-ended study responses revealed three major themes about what they wanted in future VE trainings. Specifically, the students desired (1) a more realistic virtual simulation, achieved via improved character fidelity and voice quality; (2) a wider variety of depicted medical roles and patient scenarios; and (3) more hands-on clinical interaction with immediate instructor feedback.

One participant's open-ended critique of the VE scenario noted a significant discrepancy between the virtual nurse's verbal description of the patient's wounds and the wounds as they actually appeared on the virtual patient. No other student mentioned this discrepancy.

DISCUSSION

This study aimed to develop a VE simulation environment that would immerse nursing students in a standardized training scenario. This effort to ultimately improve students' ability to effectively convey patient information to fellow nurses is part of a broad expansion of VE use in healthcare education.[31,32] Despite the general lack of significant findings in the current study, the researchers learned important lessons that will inform future iterations of the VE. Regardless of the particular metacognitive strategy utilized, study participants indicated no increase in triage knowledge as a result of watching the virtual nurse perform a triage assessment in the VE simulation. Results from the pre-post assessment might have differed from expectations because the items did not directly relate to the virtual simulation itself. This discrepancy might have prevented students from gaining new clinical knowledge from watching a single computer-based

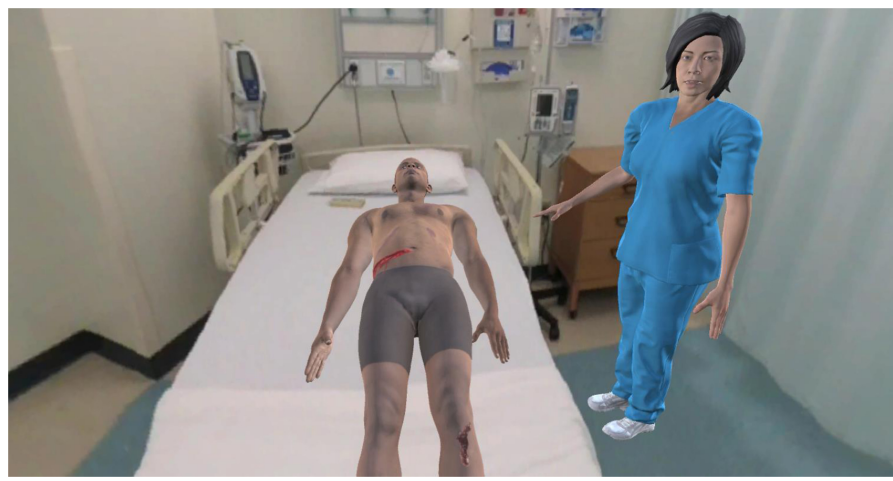

Figure 2. Online study design: desktop using a 360 image for environment. Sample transcript: Virtual nurse avatar asks patient, "What brought you to the ER today?"

Table 2. Pre/Post-Test Participant Triage Knowledge, SBAR Means (Ms), and SDs

	Question Group (n = 38)		Prompt Group (n = 31)	
	M	SD	M	SD
Pre-triage test score	51.6%	11.1%	53.0%	11.6%
Post-triage test score	49.3%	10.1%	53.0%	9.0%
SBAR test score	75.5%	12.6%	74.6%	12.5%

scenario. In future VE iterations, either the assessment items will be updated to better correspond to the simulation, or the scenario(s) will expand in variety and scope to better facilitate triage knowledge acquisition.

The multiple-choice testing format effectively measured the nursing students' ability to use the SBAR method. Participants scored an average of ~75% on the SBAR-related items, indicating they were able to accurately apply the knowledge gained watching the triage scenario (see Table 1, items 6–10). (There were no participant complaints about the format of the SBAR evaluation.) One pitfall of the single-scenario training approach is that it can be difficult to measure changes in clinical communication skill levels among novice nursing students. With this limitation in mind, we asked students if they believed watching the virtual nurse perform a triage assessment would help them do the same on a virtual patient in the future. Approximately 68% of students agreed to some degree that watching the simulated triage was beneficial, indicating the VE improved student confidence in their skills. With further refinement, we believe that this method of knowledge acquisition can provide a scaffolded learning instrument for students to improve their SBAR communication ability. For example, in the future, nursing novices can begin with multiple-choice assessment questions and progress to more open-ended responses as their experience and confidence increase.

Participant feedback included a desire for (1) a more realistic virtual simulation, achievable by improving the characters' fidelity and voice quality; (2) a wider variety of medical roles and patient scenarios portrayed; and (3) more hands-on training interactions with immediate instructional feedback. Prior research indicates VR is an immersive and interactive user experience.[16,33] We believe that, if the emergency department simulation had been presented in a VR format as originally planned, there would have been far fewer participant concerns about inadequate character fidelity. Based on the VE feedback, future design iterations using Qualtrics should include prerecorded human voices instead of computer-generated voices to improve simulation realism and participant immersion, multiple patient scenarios to provide a greater variety of clinical training opportunities, and immediate instructional feedback on the students' use of the SBAR communication instrument rather than the feedback being provided after the study questionnaires. Together, these adjustments should significantly improve the user experience for nurses in training.

The results from this study align with Orem's self-care theory and investment theory. As to Orem's self-care theory, the use of the SBAR instrument via the VE and the Qualtrics survey reinforces proper professional communication behavior, with the feedback at the end of the simulation acting as the positive reinforcement for good performance. This aligns with self-care theory, as the feedback can improve communication for better patient outcomes. VE also allows instructors to quickly provide feedback to students to address incorrect student clinical behavior taking place within a virtual environment. This work in particular offered individualized feedback

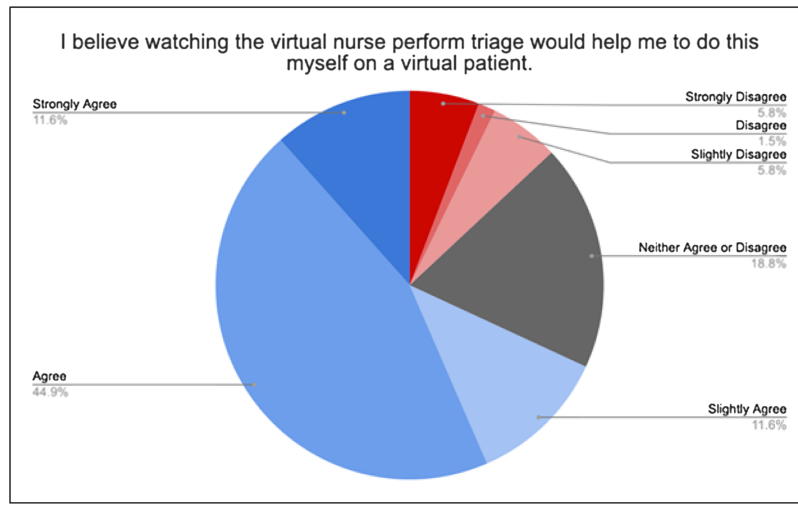

Figure 3. Distribution of participant perception of effectiveness of the VE simulation (N = 69).

to students by showing students which questions they missed and providing the correct answers within Qualtrics after the completing the final study questions. As to investment theory, students in general are satisfied when there is a positive return on their commitment of academic time, energy, and effort.[24] In the current study, results of item 18, "I believe watching the virtual nurse perform triage would help me to do this myself on a virtual patient," indicated students believed that watching the triage assessment would help them later perform an assessment themselves (see Student Evaluation section). This suggests that students were invested because this simulation would help them to improve their skills when working in simulations in the future. This also indicates that virtual humans can effectively serve as behavioral models for nursing students and that students were satisfied with the simulation.

Although participant feedback indicates there is room for improvement in updated versions of this VE educational exercise, the overall virtual immersion structure effectively allowed students to practice and assess their SBAR communication skills. By expanding this structure to include more medical scenarios and better instructor feedback, we believe that the quality and benefits of the VE will increase in the future. By modeling proper professional behavior, a well-designed VE simulation allows nursing students to develop crucial clinical skills and confidence in a safe and supportive setting.

Unexpected Findings

As previously noted, one study participant mentioned a discrepancy between the verbalized assessment of the nurse avatar and the injuries exhibited by the virtual patient. The virtual nurse identified the wrong leg while describing the patient's injury. If this happened in real life, it could be a serious, even life-threatening, mistake. Alarmingly, only one participant out of the 69 enrolled in the study mentioned this error in the free-response section of the VE evaluation. It should be noted that, due to the unexpected nature of the error, there was not an explicit section for students to mention the error, though we believe that the other 68 students either did not notice the error or believed that this error was not important enough to mention in their feedback on the simulation. Both possibilities are very concerning. A similar inability to spot the error in a virtual simulation occurred for White et al[18] when 87% of students failed to notice a fatal drug error. These findings together suggest that students may have difficulty noticing errors that are committed by virtual humans, though more research is needed to determine the actual reason for this almost universal oversight. Additionally, we believe that high levels of trust among students when immersed in the VE scenario may have impacted their ability to identify errors made by the nurse avatar. Further analysis, with trust examined as a central hypothesis for VE, is needed to alert students and instructors alike of the potential risks if undetected problems like misidentified patient limbs are carried over from the virtual realm into the real world.

LESSONS LEARNED

The study results provided several key lessons. First, largely passive VR simulations can be converted into a quality screen-based VE. (This became necessary when the COVID-19 pandemic made the use of head-mounted VR displays in a traditional academic setting impossible.) However, the immersive quality that makes VR an attractive technology may have suffered because of the modality conversion. Future research should explore VE modality differences and how they impact learning. Second, the discovery of an error in the virtual nurse's SBAR report was unanticipated. In addition to highlighting the need to be more attentive when designing and reviewing VE elements in the future, the fact that the significant discrepancy was only noted by one student raises larger educational concerns. After consultation among the researchers, we determined it is necessary to review important VE simulation constructs surrounding student trust and error reporting. The question arose whether nursing students place an unhealthy degree of trust in virtual humans as behavioral models for learning, automatically believing whatever they see is true. This leads to the next lesson learned. Third, as long as simulations are designed by humans, there is always a risk of unintentional errors appearing in the virtual scenarios. The VE in this study was collaboratively built by multiple professional researchers. Despite this, everyone involved overlooked the error in the design process. It is unclear if a different VE design, one focused on determining if students detected a medical error intentionally included in the scenario, would have resulted in more than just one student doing so. Future research controlling for altered avatar scripts could help answer questions about the realities and risks of high VE trust levels. Finally, expanded professional collaborations during medical simulations, such as between nurses and physicians, could produce different study findings. This is an important area for exploration because collaboration between different types of healthcare professionals is common in modern medical settings and non-nurses do not always use a standardized instrument like the SBAR to communicate vital patient information.

FUTURE WORK

As previously noted, there are several opportunities for future research to examine the role of VEs in nursing education in more detail. Areas of interest include the use of VE for healthcare communication and interprofessional collaboration, as well as the theoretical framework that explains the influence of virtual simulations on subsequent nursing

behavior. Overall, our study findings support VEs as an effective teaching and learning modality. However, we also recognize the system design could be improved. Of particular importance, errors within the VE (such as the virtual nurse's verbal misidentification of the patient's wounded leg) need to be eliminated unless such errors are intentionally included for research purposes. Other future improvements should include more realistic avatar characters, along with an expanded number and variety of simulated medical settings and patient cases. Finally, the effects—and potential risks—of nursing students placing a high level of trust in virtual human behavior warrant further examination.

Limitations

This study had several limitations. Researchers originally planned for study participants to utilize computers with VR headsets in an in-person academic setting. Because of COVID-19 restrictions, the virtual scenario shifted to an online format without headsets. The researchers initially feared this change in VE modality would damage the quality of the user experience and therefore lower the quality of the study. In the end, however, the modified learning experience was effective—though it is unclear how it would compare with the originally planned VR modality in terms of student satisfaction and knowledge acquisition. Another limitation was the homogeneity of the study participants. The VE training was only offered to graduating BSN students at a single large southeastern university. Any generalizable conclusions about learning experiences would require a broader, more inclusive participant population. In addition, demographic variables could be collected for future studies. Also, the median time frame for participants to complete the VE was 14 minutes, whereas the average time to complete was 17 minutes. A slower, more prolonged exposure to the VE simulation could generate different study results and should be explored. Finally, due to the unexpected nature of the error in the simulation, students were not provided an explicit space to state whether an error occurred and were not immediately debriefed on the existence of an error. This should be remedied in future work to allow for more clarity on the impact of the error and to improve student learning.

CONCLUSION

This study highlights the value of using VE as part of undergraduate nursing education. Continued evaluation and revision of this VE simulation should eventually yield an evidence-based learning modality that can be widely used in nursing programs with positive educational outcomes. Given the importance of effective nurse-to-nurse communication in ensuring optimal patient treatment, this virtual simulation has the potential to significantly improve healthcare for millions of individuals across the country.

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