Learning simulation combined with Virtual Reality has been widely used for nursing education to gain more knowledge during skills training and a better understanding of the clinical settings. Many studies have reported that nurse students are lack of knowledge about their professional clinical settings which might lead to error in conducting medical procedures. However, studies in the use of VR for nursing simulation still focus on skill materials and visual stimuli. This paper proposes a study on auditory stimuli for VR application for pre-registered nurses’ education in critical care settings. Auditory stimuli were ambisonic files recorded at the foot of the patients’ bed and nursing station. These files are then decoded into 7.1/stereo with head tracking system. Thirty-seven students at their final semester participated in this study joined the classical class (class session and field trip) and audio class (listening to audio files). The subjective assessment were taken after every class session to identify which sound is perceived as audible, important, and annoying. The acceptance of students to the additional audio media were also investigated. The results prove that the knowledge of student nurses about their clinical settings are adequate since they can determine audible and important sounds. However, their expectation about annoying sounds are clearly different. Furthermore, this proposed media are highly acceptable by the students so it can lead a significant improvement of their comments between classical and audio class.

Keywords: virtual reality, nursing education, auditory stimuli, critical care settings.

1. Introduction

In this era of massive technologies, implementation of virtual reality has been widely used for clinical simulation. It can be delivered as semi-immersive VR by developing web-based simulation and using head mounted display [1, 2] as well as fully immersive VR as reported by [3]. However, most of the reported studies are only focused on the skill materials and visual stimuli rather than the effort to provide a more realistic sound environment. The research about developing based-VR simulation for nursing education has been reported. The virtual reality environment has been built in many forms and purposes. For instance, web-based virtual simulation using Second Life® has been used to investigate safety issue with medication, interpersonal communication, and priority settings [1].
The ability to be adaptive with sound environment is necessarily important in critical care settings since the sound environment is commonly very noise exceeding WHO standard. As stated in many studies, the sound level in critical care is above the WHO standard. Several studies have reported for different critical care unit including ICUs [4], NICU [5] and Cronorary Care Unit [6]. In addition to lowering a patients’ comfort and adversely affecting the healing process, the noise environment can also interfere with the work of medical staffs and lead to medical errors [7].

Moreover, several studies have revealed a gap between practical work and theoretical studied by nursing students in academic education [8]. In some cases, it is caused by the limitation of clinical location for nursing students to be more exposed with clinical settings. Consequently, there are error / near-error situations that occur in hospitals involving novice nurses. This is also the case in nursing education in Indonesia. The learning process is still limited to the use of conventional classes, referred as classical class. Nurse students will learn about equipment and clinical procedure of critical and emergency care through text book and a short field-trip. Moreover, the students will visit the ICU room no more than 10 minutes during the field trip and therefore, they have not yet been able to gain understanding of the clinical settings especially the sound environment. This research aims to develop an additional learning media using auditory virtual reality for nursing student in completing critical care and emergency courses. The study focuses on the auditory stimuli that will be further developed as an integrated audio visual stimuli for VR system.

2. Methods

In order to create a simulation in the virtual environment, a number of auditory and visual stimuli should be determined in consideration to the computer’s capability. Creating a fully immersive virtual environment to bring the environment very similar with the reality, requires the high-computational hardware. Therefore, the simplification of adding virtual component and stimuli is sometime needed to create more readily-accessible simulator. However, this process should ensure that the system is still able to run effectively, as well as efficiently, and can be assessed to satisfy the learning outcomes.

This study is limited to the development of auditory stimuli for the VR. The stimuli materials were recorded in a standardized ICU in Indonesia using sound-field microphone at certain positions as reported in a different publication [9]. The audio files where then processed through certain techniques and will be discuss further in this paper. A questionnaire was developed for this study based on a preliminary subjective assessment with registered nurse as the respondents. The in-situ experience of the nurses were collected and defined in this study as the audibility level of sound sources in ICU. In order to assess the acceptance of proposed audio media for pre-registered nurse education, a comparative study was performed to a group of final semester student nurses in the university.

2.1 Ambisonic recording and reproduction

As stated by [9], the most frequent task being carried out by nurses are observing vital signs, providing medical care, and writing reports. To do these tasks, often times during working in the ICU, the nurse is positioned at the foot of the patient’s bed and at the nurse station area. Based on this reference, the recording was carried out for 10 minutes in each of those positions. It was performed by using calibrated Sennheiser AMBEO® VR Mic connected to H6 Zoom recorder as audio interface system with 4 input channels.

The output was an ambisonic A-format (FLU, FRD, BLD, and BRU signal). Therefore, it needs to be decoded so it could be in a readily audible format. Digital audio workstation REAPER v5.70 can be employed to process audio files by using AMBEO A-B Format Converter to produce a B-format audio. The B-format audio was then decoded using Waves Nx VST plug-in into 7.1/Stereo and applied head tracking detection from USB camera.

The audio playback was performed over Sennheiser headphone HD280 level calibrated by 45BB-4 KEMAR Head & Torso in Building Physics and Acoustics Laboratory, ITB. The listening test was carried out in a quiet room of a university clinical laboratory.
2.2 **Subjective in-situ measurement**

A preliminary subjective assessment was conducted in the highly occupied A-Class Standardized ICU of the National Hospital in Jakarta. The hospital is the national standard hospital that includes full equipment for 15 patients’ bed (13 regular beds in sharing room and 2 in isolated rooms) and the average occupancy is 60%. A number of 20 respondents (1 male, 19 females) participated with an age range of 22 – 48 y.o. All of them were registered nurse with 5-year to 30-year experience and working hours between 30 – 60 hours / week. It should be noted that the nurses in ICU are mostly wearing glasses.

2.3 **Learning Assessment**

There were 37 students (14 males, 23 females; 20 – 24 y.o) who were taking a course on Critical Care and Emergency that participated in this study. Twenty-four participants have no experience with ICU environment. Basically, the normative class includes class session and field trip to the ICU in university hospital to increase knowledge about clinical settings and medical equipment. It was a C-class ICU with 4 beds and was only occupied by 1 patient during the field trip. After completing the field trip, the students were queried about their expectation of sound environment in ICU as a future professional settings and were asked to leave a comment on the learning process.

After that, the students were invited to reserve an appointment for listening 2 audio playbacks (4 minutes each) of sound environment in ICU recorded in 2 positions in A-class standardized ICU. While listening to the audio, static position with head tracking was performed so they can feel the room impression by turning their heads in any direction as long as it is detected by camera. After listening to audio 1 (recorded at foot of the bed), they were required to answer the same questions with previous evaluation as well as after listening to audio 2 (recorded in nurse station area).

3. **Result and Discussion**

3.1 **In-situ questionnaire**

In this study, the question aims to identify the audibility of nurses to the sound in ICU environment for each sound sources as the result shown in Fig 1. The audibility level starts from 1 (inaudible) to 7 (very audible).

![Figure 1: The nurses’ audibility level of the sounds in ICU environment.](image)

The result in Fig 1 shows that the most audible sounds are emitted by medical equipment such as the mechanical ventilator, ECG monitor, infusion pump, and syringe pump. The minimum audibility level for those equipment is 3. Although the data is lower than medical equipment, the audible sound...
from patients and medical staffs can reach until level 7 by twelve and nine respondents respectively. It is around 50% participants so therefore it can conclude the sound from both sources are significantly audible.

3.2 Expected vs. Experienced Perception

A group of student nurses who were taking a course on critical care and emergency participated in this study. Subjective assessment was collected to investigate students’ expectation of sound environment after they completed a classical class (class session and field trip). Meanwhile, the perception investigation was conducted after audio intervention to listen audio 1 and 2. The questionnaire assessed their expectation and perception of audible sounds heard (level 1 to 7) in the real standardized ICU. They were also asked to decide whether the sounds are important and annoying or not to be heard. These result is presented in Fig 2.

For the audible sounds, there was insignificant difference between classical and intervention result except for the sounds from patients, office phone and bell near patient beds. Sound of ECG monitor is perceived as the most audible sound by three groups. The similar result is presented for mechanical ventilator, infusion pump, syringe pump, and medical staffs.

As with the audible sounds, the sound sources that perceived as important by participants is nearly identical between three groups. It can be seen from the mechanical ventilator, ECG monitor, and emergency trolley of which the votes are exactly the same. Although the perceptions towards important sounds between classical and intervention class increases especially for medical equipment, it moderately decrease the sounds from patients, medical staffs, office phone and bell. This probably appears because the sounds of patients, office phone and bell in recorded audio files are rarely audible. Unlikely, the sounds heard from medical staffs’ voice are increasingly audible but considered as declined importance.

![Graph](image.png)

**Notations:**
1. Mechanical ventilator
2. ECG monitor
3. Infusion pump
4. Syringe pump
5. Patients
6. Emergency trolley
7. Medical staffs
8. Office phone
9. Bell

Figure 2: Results of the subjective assessment to investigate the students’ expectation of sound environment

However, based on annoying sounds, medical equipment such as the mechanical ventilator and ECG monitor are perceived as less annoying sound sources, though they are increasingly audible and
important. That is also the case for the sounds of trolley and patients’ voice. Interestingly, since the medical staff’s voice tends to be audible and important, it is increasingly perceived into annoying sounds. That can be due to frequent communication between registered nurses in the real ICU. Although it is accepted as an informative contents as reported by [10], it occasionally distracts the concentration of nurses while doing their task. Moreover, a good technique to predict the range of easiness of nurses’ communication while they are continuously moving has been demonstrated by [11] focused on 2 parameters including speech privacy distance ($r_p$) and distraction distance ($r_d$).

### 3.3 Acceptance of additional media

The audio stimuli are created as an additional media for critical care and emergency course of pre-registered nurse. The subjective assessment was also conducted to evaluate the proposed learning system by comparing between classical class (I) and intervention class (II) as the result shown in Table 1.

Table 1: Results of the subjective assessment to evaluate the proposed learning system for two different classes: classical class (I) and intervention class (II)

<table>
<thead>
<tr>
<th>No</th>
<th>Questions</th>
<th>Strongly Agree (%)</th>
<th>Agree (%)</th>
<th>Disagree (%)</th>
<th>Strongly Disagree (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>I enjoyed this learning system</td>
<td>26.47</td>
<td>44.12</td>
<td>73.53</td>
<td>64.71</td>
</tr>
<tr>
<td>2</td>
<td>I could hear the ICU’s sound environment</td>
<td>32.35</td>
<td>70.59</td>
<td>67.65</td>
<td>38.24</td>
</tr>
<tr>
<td>3</td>
<td>I could see the ICU environment</td>
<td>41.18</td>
<td>29.41</td>
<td>58.82</td>
<td>67.65</td>
</tr>
<tr>
<td>4</td>
<td>Learning hours were sufficient</td>
<td>0.00</td>
<td>5.88</td>
<td>11.76</td>
<td>47.06</td>
</tr>
<tr>
<td>5</td>
<td>The ICU for field trip was very satisfying</td>
<td>14.71</td>
<td>23.53</td>
<td>61.76</td>
<td>64.71</td>
</tr>
<tr>
<td>6</td>
<td>The tutor explained clearly</td>
<td>11.76</td>
<td>17.65</td>
<td>61.76</td>
<td>70.59</td>
</tr>
<tr>
<td>7</td>
<td>Overall, I liked this learning system</td>
<td>35.29</td>
<td>44.12</td>
<td>58.82</td>
<td>64.71</td>
</tr>
<tr>
<td>8</td>
<td>I need more learning hours</td>
<td>67.65</td>
<td>73.53</td>
<td>32.35</td>
<td>35.29</td>
</tr>
<tr>
<td>9</td>
<td>The learning space needs improvement</td>
<td>44.12</td>
<td>50.00</td>
<td>50.00</td>
<td>55.88</td>
</tr>
<tr>
<td>10</td>
<td>The materials provided were incomplete</td>
<td>50.00</td>
<td>58.82</td>
<td>47.06</td>
<td>41.18</td>
</tr>
<tr>
<td>11</td>
<td>This method allowed me to listen to the sound environment</td>
<td>5.88</td>
<td>47.06</td>
<td>38.24</td>
<td>50.00</td>
</tr>
<tr>
<td>12</td>
<td>This method allowed me to see the ICU environment outside the classroom</td>
<td>5.88</td>
<td>32.35</td>
<td>41.18</td>
<td>52.94</td>
</tr>
<tr>
<td>13</td>
<td>I would like to feel the sensation of the ICU room outside the classroom</td>
<td>29.41</td>
<td>55.88</td>
<td>47.06</td>
<td>44.12</td>
</tr>
<tr>
<td>14</td>
<td>Overall, this learning system needs improvement</td>
<td>61.76</td>
<td>67.65</td>
<td>38.24</td>
<td>41.18</td>
</tr>
</tbody>
</table>

Overall, the audio intervention can improve the number of votes whether it is already agree (question 1, 3, 5, 6, 7, 9, and 12) or strongly agree (question 8, 10, 14). It also successfully turns the respondents’ rating from disagree to agree (question 11 and 4) and from agree to strongly agree (question 2 and 13). This result shows that additional media such as audio recording is a promising media to be added into the learning process.

During the intervention process, several participants were moving their heads to feel the sensation of head tracking system. A short discussion was conducted after the participants filling the questionnaire. Some of them can predict the recording position from two audio files and the others can reflect a story about sound environment for example “the sound of medical equipment in audio 1 was very clear while audio 2 was dominated by medical staffs’ voice”. This also can generate a perception of participants when they were telling that, “the dominant sounds of medical equipment in audio 1 made me scary and medical staff’s voice in audio 2 was very annoying”.

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4. Conclusion

There are two conclusions that can be derived from this study. The first conclusion is that there is no significant difference of the participant’s ability in understanding the audible sound in classical class and audio class. This provides evidence that the nursing students have already received an adequate knowledge about the clinical settings in the ICU. However, the expectation of annoying sound is considerably different from the participants in these two classes. It can be concluded that an additional learning media is needed to improve their adaptation ability in the ICU as a unique sound environment.

The proposed additional media in this study has received a good acceptance by the students as the user. The acceptance level is also improved, indicated by the number of votes on several queries regarding the learning time, the usability, ability to substitute the incomplete materials, and also the ability to gain sensation of being within the environment.

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