**HOSPITAL SOUNDSCAPES: SOUNDSCAPES INTERVENTIONS IN INTENSIVE CARE UNIT**

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Acoustic environment of intensive care unit (ICU) is known to be noisy and stressful. The sounds from medical equipment and staffs’ activity are found out to give the most contribution to the overall sound level inside the ICU. Many studies have shown its negative effect on patients and staffs, both psychologically and physiologically. However, several studies also showed that the information contained in ICU soundscape is considered as important, especially for the nurses. Thus, the following question needs to be answered: “How to improve Comfortness and Dynamics level while maintaining the Information factor inside the ICU?”

Several studies have shown the positive impact of soundscape intervention on the perception of occupants in healthcare facilities. However, previous studies were mostly done from the patient’s perspective. In this study, the effect of the sound intervention to ICU soundscape will be studied from the nurse’s perspective, specifically to find out several sounds that mostly preferred by the nurses. The sound was added to ICU soundscape through soundscape simulator, and the nurses were asked to rate the soundscape. It has been found that certain sound with certain level can improve the nurse’s perception. This result can be used by practitioners to improve the soundscape while still maintaining the information content in an ICU.

Keywords: hospital soundscape, soundscape intervention, perception

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1. **Introduction**

Acoustic environment of intensive care unit (ICU) is known to be noisy and stressful. The sounds from medical equipment and staffs’ activity are found out to give the most contribution to the overall sound level inside the ICU. Many study has shown its negative effect for patients and staffs, both psychologically and physiologically [1, 2, 3]. However, several studies also shown that the information content in ICU soundscape is considered as important, especially for the nurses. Previous study in an ICU of a general hospital in Jakarta shows that according to the nurses, the most important factor of the soundscape in the ICU was Information, followed by Comfortness and Dynamics factor [4]. Thus, the following question needs to be answered: “How to improve Comfortness and Dynamics level while maintaining the Information factor inside the ICU?”

Study on hospital acoustics has began to shift from noise control approach to soundscape approach. Eliminating sound sources has no longer become the only option to improve occupant’s comfort, as studies show that implementation of appropriate soundscape can give better result [5, 6]. Many studies on hospital acoustics shows that introducing music or natural sound can increase patient’s perception towards hospital soundscape [7]. A better perception will reduce patient’s stress level, hence reduce the recovery time of the
patients. A study shows that patients who were being treated in a room with classical music required less pain medications after surgery [8].

Several studies have also done in order to figure out how introducing additional sound may improve people’s perception towards hospital soundscape. However, most of the study were focusing on the patient [9, 10, 11]. And the study were usually done in ward or surgery room. The study of hospital soundscape that focusing on the nurses in the ICU were still limited, even though the soundscape of an ICU is very dynamic. The room require a special treatment because the patients treated in the ICU needs a calm environment. On the other hand, the ICU nurses needs to be able to deliver the best treatment all the time.

This study is conducted to address perception of ICU nurses towards intervened soundscape of the ICU. The evaluation was done by doing a listening test with binaural playback system. Pre survey was done before the listening test to figured out the most preferred additional sounds to be introduced to the ICU soundscape.

2. Pre Survey

Pre survey was done in Islamic private hospital using two methods: online questionnaire and in-situ evaluation. The respondents of the online questionnaire were nurses from various hospital, while the respondents of the in-situ evaluation were the nurses who will participated in the listening test. Similar question was given to the respondents: “If you are allowed to add another sound inside the ICU, without ignoring patient’s comfort, what kind of sound do you prefer?”

A total of 57 respondents were participated in the pre survey. 31 respondents (54 %) chose Quran recitation audio, while 12 other (21 %) chose music audio. One respondent chose birds chirping sound, while the rest of the respondents prefer the existing condition.

According to the result of the pre survey, 3 kind of sounds were chosen to be evaluated in the listening test: Quran recitation audio, music, and birds chirping sound. One other sound was also chosen to be evaluated because it was said to be able to lower anxiety level, which is pleasant natural sound [12]. In this study, water flow sound was chosen to be evaluated.

3. Recording and Sound Level Measurement

The object of this research was an ICU of an Islamic private hospital in Bandung. It was located in the second floor of the main building, along with the surgery room and HCU. The ICU was consisted of 5 patient bed, 1 isolation room with 1 patient bed, and 1 nurse station. Each patient bed was equipped with standard medical equipment and was separated between each other with hanging curtain. The nurse station was located in front of the entrance door. Due to the limitation of the space, the nurse station only used by the head nurse and for storing the patient’s reports. The layout of the room is presented in Figure 1.
The hospital has several cultures that make it different from general hospital. Thirty minutes before praying time comes, quran recitation audio will be played in the rooms, including ICU. And when the praying time comes, male nurses will go to the mosque to offer prayer. Hence, during praying time, the ICU become more quiet.

Sennheiser AMBEO VR Mic and Zoom H6 to record the acoustic environment. The microphone was placed at the point of measurement. The front direction was set toward the patient's mattress with a height of 1 m. At the same time, background sound level was measured using sound level meter RION N-28. The SLM and microphone was placed next to each other. When the measurement took place, all the curtain was opened as shown in Figure 2. The measurement was done from 11 AM to 5 PM. During the measurement, activities in the ICU were going as usual.

4. **Listening Test**

4.1 **Respondents**

Respondents of the test were the nurses of the ICU. 9 male and 12 female nurses were participated in the test. Every nurse work 48 hours per week in average with working experience ranged from 6 months to 17 years.

The nurse’s working hour was divided to three period of time: 07.00 AM – 1.30 PM, 1.30 PM – 7.30 PM, and 7.30 PM – 7.00 AM (on the next day). There are 6 nurses on duty for each shift which make it 18 nurses on duty each day. Two head nurses responsible in managing the activity inside the ICU were working in rotation for 12 hours each.
4.2 Questionnaire

The questionnaire used in the test was divided into 2 sections. The first section was consisted of demographical questions, while the second one was consisted of a set of semantic scale used to assess the audio stimuli. The semantic scale set used in this test was the same as the one used in the previous study [4].

4.3 Simulator

The listening test was done using the soundscape simulator as previously used in another study on urban soundscape [13]. However, the playback system used in this test was binaural playback system. This system was chosen for its flexibility compared to multi-speaker system. Audio Technica ATH-M50 was used during the test.

The recording from Sennheiser AMBEO was decoded into stereo signals using Reaper. The audio was then calibrated by using KEMAR dummy-head connected to Real Time Analyzer (Figure 3).

![Figure 3: Calibration Process](image)

During listening test, the respondents were requested to add sound source and adjust the sound source with the recording of ICU played in the background. The interface of the experiment is shown in Figure 4.
4.4 Procedure

The listening test was carried out in the consultation room of the ICU. The nurses were asked to assess three audio stimuli by using the semantic scale: 1. Soundscape of the existing room; 2. Playback of the recorded soundscape; 3. Playback of the recorded soundscape with additional sound.

4.4.1 Stimulus 1 – Existing soundscape

The respondents were asked to listen and recalling the soundscape of the existing room and rate the soundscape by using the semantic scale. The result of the first stimuli was used as a baseline.

4.4.2 Stimulus 2 – Playback of recorded soundscape

The respondents were asked to listen to recorded audio of the ICU soundscape through headphone. The level of the audio could not be adjusted. The respondents were then asked to rate the audio.

4.4.3 Stimulus 3 – Recorded soundscape with additional sound

The respondents were asked to listen to similar sound with stimuli 2. Then the respondents were asked to choose another sound to be added. The respondents were allowed to listen to all additional sound and adjust the level before choosing the most comfortable one according to each respondent. After choosing the most comfortable sound, the respondents were asked to adjust the level. Then the respondents were asked to rate the audio.

5. Results

5.1 Preferred Additional Sound

The listening test shows that most of the respondents (90 %) were choosing Quran recitation sound as additional sound with average level of 68.18 dBA, while water sound and classical music only being chosen by 5 % of the respondents with average level of 65.84 dBA and 61.69 dBA respectively. On the other hand, there was no respondent who chose birds chirping sound to be added.

This result shows how context highly affect people’s preferences [6]. The respondents have been used to hear Quran recitation sound during their working hour. Hence most of respondents chose it to be added to the recording sound. On the other hand, there were no respondents who chose birds chirping sound because the sound was contextually unsuitable for ICU. The other reason was because birds chirping sound is not a continuous sound. This made it unable to mask sounds inside the ICU.
5.2 Significance Analysis

T-test was done to compare respondent’s perception to the stimulus 1, 2, and 3. Table 1 shows t-test result between respondent’s perception to stimulus 1 and stimulus 2. As shown in the table, the value acquired for all scale is more than 0.005. This indicates that stimulus 1 and stimulus 2 gave a relatively similar perception to the respondents. Hence, the recorded sound can be said as represented the soundscape of existing condition.

On the other hand, table 2 shows t-test result between respondent’s perception to stimulus 2 and stimulus 3. The results shows that the additional sound gave significant effect to 5 semantics: Anxious – Calm, Unpleasant – Pleasant, Uncomfortable – Comfortable, Soft – Harsh, Complex – Simple. These semantics were related to Comfortness and Dynamics factor. On the other hand, the semantics that were related to Information factor were not affected significantly with addition of another sound in the ICU.

Table 1: T-test Result - Respondent’s Perception to Existing Soundscape vs Reproduced Soundscape

<table>
<thead>
<tr>
<th>Semantic Pair</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anxious – Calm</td>
<td>0.100</td>
</tr>
<tr>
<td>Unpleasant – Pleasant</td>
<td>0.205</td>
</tr>
<tr>
<td>Flat – Dynamic</td>
<td>0.649</td>
</tr>
<tr>
<td>Uncomfortable – Comfortable</td>
<td>0.125</td>
</tr>
<tr>
<td>Harsh – Soft</td>
<td>0.087</td>
</tr>
<tr>
<td>Unclear – Clear</td>
<td>0.025</td>
</tr>
<tr>
<td>Loud – Quiet</td>
<td>0.457</td>
</tr>
<tr>
<td>Uninformative – informative</td>
<td>0.901</td>
</tr>
<tr>
<td>Complex – Simple</td>
<td>0.043</td>
</tr>
</tbody>
</table>

Table 2: T-test Result - Respondent’s Perception to Reproduced Soundscape vs Reproduced Soundscape + Additional Sound

<table>
<thead>
<tr>
<th>Semantic Pair</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anxious – Calm</td>
<td>0.000</td>
</tr>
<tr>
<td>Unpleasant – Pleasant</td>
<td>0.002</td>
</tr>
<tr>
<td>Flat – Dynamic</td>
<td>0.023</td>
</tr>
<tr>
<td>Uncomfortable – Comfortable</td>
<td>0.000</td>
</tr>
<tr>
<td>Harsh – Soft</td>
<td>0.001</td>
</tr>
<tr>
<td>Unclear – Clear</td>
<td>0.252</td>
</tr>
<tr>
<td>Loud – Quiet</td>
<td>0.032</td>
</tr>
</tbody>
</table>
To analyze more how the additional sound affect respondent’s perception, the average rating of the semantic scale was plotted as shown in Figure 5. The error bar was added to ease the interpretation of the graph. From the graph we can see that almost all of semantic rating for reproduced soundscape + additional sound was higher than reproduced soundscape only, indicating that the additional sound can increase respondent’s perception. The difference is quiet large, except for the Unclear – Clear, Uninformative – Informative, Flat – Dynamic, and Loud – Quiet scale. If we relate it to the t-test results, we can conclude that the additional sound can increase respondent’s perception for the scale that related to Dynamics and Comfortness factor significantly without incurs information loss. However, we should note that this is respondent’s subjective perception. Additional cognitive study is required to clarify this result.

![Figure 5: Average Value of Respondent’s Perception to Existing Recorded Soundscape and Recorded Soundscape + Additional Sound](image)

**Figure 6: Average Value of Respondent’s Perception to Existing Recorded Soundscape and Recorded Soundscape + Additional Sound**

### 6. Conclusion

This study shows that introducing additional sound to the soundscape of the ICU can improve the perception of the nurses without incurs information loss. The results also show that context can affect the preference of the additional sound. In this study, the respondents were used to listen to Quran recitation sound during their working hours. Hence, most of respondents chose Quran recitation sound to be added to the recorded soundscape. Different results may occur in different hospital as the culture may be different.

### REFERENCES


