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SURGERY SOUNDS AND PATIENT EMOTIONS: THE IMPACT OF SOUNDS ON THE EMOTIONAL EXPERIENCE OF PATIENTS IN OPERATING ROOMS

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ABSTRACT

Orthopedic surgeries are identified as one of the noisiest operations in the OR (operating room). Sounds of patient monitoring and support devices, conversations, and surgical tools contribute to the complex acoustic environment. Certain orthopedic surgeries require spinal anesthesia, making patients half awake and exposed to surgical sounds. Therefore, the emotional experience of patients toward OR sounds requires more attention, especially considering the different phases of the surgery (pre-operative, operative, and postoperative). This study aims to discover the connections between sounds and the difference in the emotional experience of orthopedic OR patients. In this paper, a questionnaire-based study with a forced choice was conducted employing a Chi-Square analysis of the data. Patients (n=64) with different levels of anesthesia were asked to remember which sounds they heard and what emotions they experienced by picking one or more from the available set of emotional experiences. The results suggest that emotions like nervous, curious, and relaxed are likely to be influenced by the sound types, anesthesia types, and surgery phase. As a secondary aim of the study, the possibility of music as a design intervention to act as a sound-masking and relaxation is investigated.

Keywords: *orthopedic surgery, acoustic environment, anesthesia, emotional experience, operating rooms.*

1. INTRODUCTION

Noise in Operating Rooms (OR) is a widely acknowledged issue and listening in the OR is an active but also a collective experience in an acoustic environment which patients and OR staff members coexist [1]. In orthopedic surgeries specifically, medical staff has an average exposure to excessive noise of 19-37 minutes and the equivalent sound pressure can be around 66.5 dBA [2] with peaks reaching 120-140 dBA [1]. Occasional high-spectrum sounds in surgeries such as TKR (Total Knee Replacement) and THR (Total Hip Replacement) causes an evident impact on medical staff and patients [3] and therefore interferes with the surgery process. Typical sounds that can be found in the perioperative period include surgical instrument (tool) sounds, medical device sounds such as monitors, alarms, and suction apparatus, and sounds that come from humans such as speech [4]. Surgical tool sounds result in high sound pressure levels when operating on bones. For example, Anspach drill can reach 100-120 dBA on the bone at 80k rpm (revolutions per minute). While for a cast cutter saw, sound pressure is measured to be between 80-100 dBA on the bone [3]. Patient monitoring and support devices produce repetitive and constant sounds such as beeping and humming [5]. Due to the demand for communication during surgeries, surgeons and nurses are likely to talk with each other with a loud voice, which produces a sound pressure of around 70-85 dBA, to keep the loudness 15 dBA above the OR sounds to ensure effective conversation [2].

Patients exposed to such complex soundscape will likely to suffer from negative emotions [3]. Especially with spinal anesthesia in TKR and THR [7-8], the awareness or responsiveness of the patient becomes higher [9]. For patients who are under general anesthesia, noise still tends to be the most stimulating factor among all in the review article by Bischoff, et al [10]. The complex soundscape

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inside OR is likely to cause hypertension [11], which causes a faster blood flow [12] and covers the vision of orthopedic surgeons. Noise may also stress patients and increase annoyance or other negative feelings. In the research of Liu and colleagues [13], one-third of the patients claimed that the surgery induction and recovery phases were noisy.

Sounds in general can evoke emotional reactions and affective responses [14]. Research on patient emotions towards the soundscape in orthopedic OR has been scarce compared to those on the medical staff. Whether from a clinical care perspective or the effectiveness of anesthesia and surgery, the emotional change of patients should be taken into consideration. As the patient may also go through negative emotions in post-surgery [15], an improvement in surgery experience might also contribute to the psychological recovery after surgery. Emotions like anxiety and fear evoked by the complex soundscape inside OR can be easy to understand. However, certain hospital sounds can evoke neutral feelings or even positive feelings such as relaxed, relief and curious in addition to negative experiences such as nervousness, tiredness, anxiety, fear, and depression [16].

Emotional experiences can also be dependent on the anesthesia type or surgery stage. Unlike spinal anesthesia, general anesthesia is more often used in orthopedic surgeries to avoid anxiety [9]. Moreover, sounds can have an effect before the surgery starts and when surgery ends, rather than merely during the operating period as the noise could occur already when patients are ready to receive anesthesia [17]. The simple humming sound of the equipment could reach up to 20-60 dBA when no one is inside the OR [3]. Noise could also be perceived during the recovery phase when patients were put in the anesthesia recovery room [13].

To be able to improve the circumstances of patients it is important to study the role of all types of OR sounds in patient experience. Music is commonly found in ORs comforting mainly surgeons [1]. Music often appears as a proxy for sound stimulation, as it can have a strong impact on psychological changes [18]. In the research of Alvin and Andrews in 1975 [19][20], music therapy is used as a way of building up communication between children and parents and is found to be effective in dealing with depression and anxiety [21]. Thus, some sounds may have a positive impact on patients' emotions.

1.1 This study

Our primary goal is to find out the possible impact of different sounds inside the OR on the emotional experience of patients undergoing orthopedic surgery. In this study, we mainly study four kinds of sounds that may occur inside the orthopedic OR: (1) Conversational sounds (CS) such as medical staff discussions or verbal communication between patients and anesthesiologists. (2) Patient monitoring and patient support devices sound (PMSDS) including alarms and machinery sounds such as humming. (3) Surgical tool sounds (STS) which are used during orthopedic surgery. (4) Heartbeat & breath sound (HBS) including patient's own heartbeat or breath sounds. These sounds are part of sound categories that are validated in previous research [22].

Overall, as a secondary aim of the research in this paper, we will investigate whether anesthesia type and surgery stage have an effect on patients' emotions. We will compare patients' emotional experiences under General Anesthesia and Spinal Anesthesia under different surgery stages (before during and after). The three stages include before surgery stage (when they were wheeled into the OR and waited for anesthesia), during the surgery stage (after anesthesia and surgery procedure officially began), and after surgery stage (when the surgery was completed and they were transferred out of the OR).

Our investigations will provide further evidence for how technology induced sounds negatively influences the experience of patients in ORs. Not many interventions take place for reducing the negative impact of sounds. As a third aim, we will reflect on possibilities with sound-driven design for OR.

The research was carried out in two phases using qualitative and quantitative methods. In the first phase, a questionnaire focused on discovering the sounds that patients heard during orthopedic surgery and how their emotions changed during this period. The second phase had two parts: the expert interview and the patient interview, and it focused on exploring the listeners' preference for the music that will be played during the surgery.

2. METHODS

2.1 Patient questionnaire

In the first phase of research, the questionnaire was made based on the aim of understanding what the patients claimed they have heard inside the orthopedic OR, and how their emotions changed during different stages. Since there was no mandatory requirement for the type of anesthesia before the questionnaire was distributed, patients who participated in the study would be under general or spinal

anesthesia. Questionnaires were handed out by medical staff to patients who had finished their surgeries.

2.1.1 Ethical and methodological concerns

As the questionnaire may involve questions that are about the privacy of patient conditions, each participant was asked to check informed consent before entering the survey. They were told by the medical staff that this survey is not mandatory, and they could quit whenever they wanted to. If they would not like to share their surgery experience, they were allowed to check "no" at the very start and then end the survey. In the questionnaire, we did not ask for private information such as names or attending doctors to keep the data anonymized. In order to get a better understanding of the patient's desired sound environment inside the OR, besides the multiple-choice questions, patients were asked to complete several fill-in-the-gap questions as a simple interview at the end. The study was approved by the TU Delft Human Research Ethics Committee (2619-2022).

2.1.2 Participants

Participants in this research were all patients recruited from China mainland, aged between 18 to 60 and above, with a gender ratio of 2:1 (Female: Male). The total number of the questionnaire collected was 69, with the effective questionnaire number of 64 (3 refused to share their information, and two did not receive anesthesia). Patients were contacted by local medical staff, who asked for voluntary participation after their orthopedic surgeries. Questionnaires are collected anonymously from several hospitals in the western and central part of China.

2.1.3 Research procedure

This research was conducted through the online survey platform "Wen Juan Xing". The platform allowed questionnaires to be generated into a QR code, therefore, the medical staff was asked to hand out the QR code to patients who went through the surgery and were willing to share their experience. Most of the patients were able to scan the QR code through WeChat, which made the data collection easier. For those who were unable to use smartphones, medical staff helped them fill out the online survey by asking them questions in person.

Questions were set according to the two types of anesthesia (general or spinal), and the only difference is patients who received general anesthesia were not asked to reflect on their emotions during the surgery, as it was assumed that they have little or no consciousness during that period. All data collected were downloaded from the online platform, anonymized, and analyzed by the first author.

There were mainly three parts in the questionnaire. Patients were first asked for their surgery and anesthesia types. The anesthesia type included General Anesthesia (GA), Spinal Anesthesia (SA), and Others. SA patients were asked about their emotional experience regarding three different stages of the surgery: Before, During and After. GA patients were asked to choose one to three emotions that would fit them the best regarding their overall emotional experience. The emotion descriptors were Neutral, Confused, Nervous, Tiring, Relaxed, Fear, Relieved, Anxious, Curious, Depressed, and Others. These terms are key words extracted from previous studies on patient emotions [16]. All patients were asked to recall what they heard inside the orthopedic OR, and what was the most impressive sound event they remembered. They were able to choose sound category options including Conversational sounds, Patient monitoring & support sounds, Surgical tool sounds, Heartbeat & breath sounds, and Others. Afterwards, patients' attitudes towards the acoustic environment inside the OR were investigated, as well as their satisfaction level with the whole surgery experience. They were also asked for their willingness to have music in the OR and if so, what kind of music would they prefer. Lastly, general information like gender and age were collected at the end of the survey. The questionnaire was in Mandarin for better understanding and efficiency for the Chinese patients.

2.1.4 Data analysis methods

There were two different parts of data that needed to be analyzed. Quantitative results from questionnaire such as the emotional descriptors' frequency count for each surgical phase, would be exported from the online platform and analyzed in SPSS. The data would be first described at a general level, and then a correlation analysis were conducted. Since all the questions regarding sounds and emotions were binary questions, Chi-square was used to find out the factors with significant relationships. Significance was measured at .05 level. Patients who received spinal anesthesia were analyzed first, which was 51 subjects out of 64. Then in order to see the impact of anesthesia types on patients' emotions, 13 subjects were randomly taken out, and mixed with the 13 subjects who received a general anesthesia to eliminate the possible error caused by a large difference in the number of subjects.

2.2 Interviews on music inside the OR

To further understand the possible positive emotional impact of music on patients and medical staff alike, interviews had been conducted with orthopedic surgeons, patients, and an anesthesiologist. The interviews were semi-

structured and mainly focused on how medical staff and patients would react to music inside the OR, and whether it would help improve the emotional experience of the surgery for them. It is worth mentioning that one of the surgeons had tried to play music during his surgery ever since he helped with the first questionnaire survey, therefore, some useful feedback was also collected throughout the conversation.

For surgeons, questions about what kind of surgery is the loudest and makes more noise were asked, followed by their attitudes toward the current acoustic environment in the OR. Then the preference of music types was discussed, both for their patients, colleagues, and themselves. For patients, their feelings inside the OR were mainly talked about. The anesthesiologist, besides the music during surgery, was also asked about how they would usually keep the patients under the optimum condition while operating. The interviews were conducted online since the patients were in different locations. Sixty-four patients participated in the survey. Three surgeons and one anesthesiologist were invited for an interview.

3. RESULTS

The results of the research will be presented according to the research questions: (1) Whether different sounds that patients heard inside the orthopedic OR causes different emotions. (2) Whether other factors such as anesthesia type and surgery phase influence patients' emotions (3) Whether the sounds that patients heard inside the OR would affect their willingness to hearing music or not during surgery. Results are presented in three parts. The first part is of the 51 patients who receive spinal anesthesia (SA), such as their emotional experience and perception of sounds inside the OR. The second part is a comparison analysis between the SA and GA patients. Finally, the interviews are analysed, and presented in quotes with the insights gathered.

3.1 SA patients' perception of sounds inside the OR

Patients were first asked about their consciousness and what they thought they have heard inside the OR. For SA patients, 20 patients were fully conscious (less than half) and 26 were half awake (more than half), and only five were unconscious after anesthesia (see Figure 1). The type of sounds they heard inside the OR were mainly patients monitoring & support sounds (PMSDS), conversational sounds (CS), and surgical tool sounds (STS). Only 7 patients claimed that they heard their heart beating sounds or breathing sounds (HBS), and unconscious patients declared to hear nothing. When asked to recall what was the most remarkable sound event they experienced during the whole surgery period, 37 patients heard patient monitoring and support devices, 33 heard conversations between medical staff and them, or within medical staff, 30 heard surgical tool sounds.

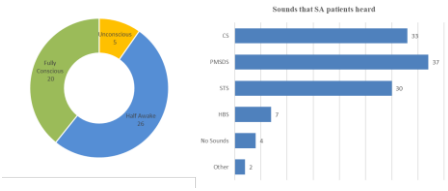

Figure 1. Consciousness of Spinal anesthesia (SA) patients during the surgery (Left). Sounds that spinal anesthesia patient heard during their surgeries (Right). (CS: Conversational sounds; PMSDS: Patient monitoring & support sounds; STS: Surgical tool sounds; HBS: Heartbeat & breath sounds). Total n=51.

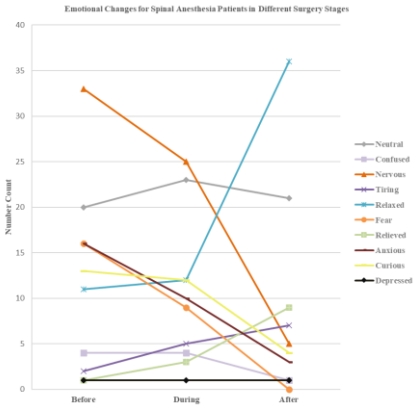

Figure 2. Spinal anesthesia patients' emotional change during three different stages of orthopedic surgery.

3.2 SA patients' emotional experience

SA patients were asked to write down their emotions at three different stages of the surgery (See Figure 3). They were given 10 emotions both positive, negative, and neutral to choose from and were able to choose up to three emotions at each stage. In Figure 2, a line chart shows how many patients choose a certain emotion at one of the three stages, and how the number count is changing. Nervous, neutral, fear and anxious are the most chosen emotions before the surgery (n=33, n=20, n=16, n=16, respectively), whereas relaxed, neutral, relived and tiring are picked by more patients after surgery (n=36, n=21, n=9, n=7,

respectively). During surgery, besides an obvious decrease in negative emotions, e.g., nervous, we saw an increase in neutral, relaxed, and tiring. Number of patients who chose curiosity decreased during the surgery and rapidly declined after surgery. Few patients felt confused (n=4) or depressed (n=1), compared to the large number of patients who felt neutral the whole time.

Figure 3 presents the emotional experiences of SA patients with different types of OR sounds. In the figure, the vertical axis represents the number of people who have a certain emotion. Due to the difference in the number of people hearing the four kinds of sounds, the general number count of emotions may vary. The general trend of the change of each emotion is similar to Figure 2. Patients who heard PMSDS seem to be more nervous before and more relaxed after surgery.

In order to have a more detailed picture of the relationship between the emotional experience and sounds SA patients heard, a Chi-Square test was carried out. Results suggest that patients who heard CS inside the OR were more likely to feel nervous before the surgery (p=.025), while those who heard HBS may be fearful after the surgery starts (p=.043). During the surgery, patients generally did not feel too curious, however, if they heard STS, they might get curious (p=.049). If SA patients heard STS inside the surgery room, patients experienced relaxation (p=.003) and delight (p=.017) after the surgery. As for some patients who heard PMSDS inside the OR, feeling relaxed after the surgery is a possibility (p=.047).

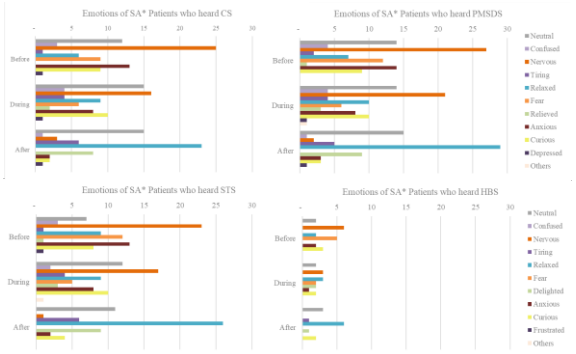

Figure 3. SA (Spinal anesthesia) patients' emotional experiences with different types of OR sounds.

3.3 Patients' satisfaction with surgery experience.

Patients were also asked to fill out what they thought of the surgery experience, and if they had a chance, whether they would be willing to listen to music during the surgery. Forty-five of the 51 patients were (very) satisfied with the surgery experience. Among the three who were not happy with the experience, two of them claimed that the environment was too noisy and one suggested that the OR room is not spiritually a nice place to stay. Nearly half of the patients (25 out of 51) were willing to listen to music during the surgery, and four of them were uncertain, with 22 against the proposal. A Chi-Square test was also done between the sounds patients heard and their willingness to hear music, patients who heard STS were likely to be willing to hear music while surgery (p=.027), but for other sounds, no significant correlations were found (p>.100).

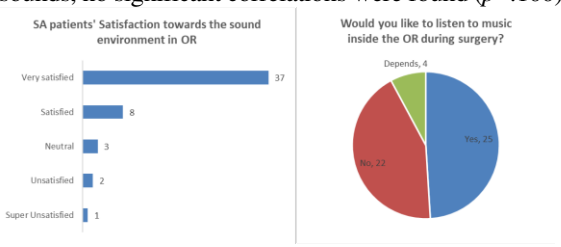

Figure 4. SA patients' satisfaction towards the sound environment inside the OR, and willingness to listen to music during the surgery.

3.4 Patients' anesthesia type and their emotions before and after surgery

To find out whether anesthesia type also has an impact on patients' emotions before and after orthopedic surgery, 26 subjects (13 results randomly taken out from the 51 SA patients to equate the 13 GA patients for comparison) were mixed and a Chi-Square test was done. Test results suggest that anesthesia type does affect some emotional experience of patients. For example, after the surgery, GA patients tended to be more neutral than SA patients (p=.005). However, SA patients seemed to feel more relaxed than GA patients (p=.006).

3.5 Preferences for Sounds and Music in the OR

During the interviews with orthopedic surgeons and patients, questions about sound and music were mainly talked about. Sounds can mean differently for orthopedic surgeons and patients. For the medical staff, certain tool sounds and alarm sounds support them in better knowing the surgery procedure and patient status. For example, when using the drills, surgeons determine the depth of the drill by listening to the change in the sounds. While for patients, those were simply noise with alternating frequency. From the perspective of medical staff, they did not want their conversations to be overheard by the patients, no matter

private or not. During the rather long surgery period, surgeons and nurses talk with each other about topics that are not related to the ongoing operation, so it would be fine for them to listen to some music or radio when skillfully performing the task on hand.

When interviewing, the anesthesiologist mentioned that the sense of hearing would be the last sense to go after anesthesia, so having auditory intervention during the surgery could be useful for patients. When asked about the type of music played during the surgery, the expert was uncertain about the level of music appreciation of patients and therefore suggested that to be careful when choosing the music.

One orthopedic surgeon has been playing music for his patients since August 2022 (two months before the interview). Interestingly, the surgeon would choose the music he prefers to listen to rather than ask about the patient's preferences stating "Since I am the one who will listen to this music the longest, why not?" When asked about the feedback from the patients, he said that they all enjoyed the songs played, no matter whether it was pop, classical, or light music. "The music won't influence me in the THR surgery, and I think the music is not as that loud as the surgical tools." The surgeon also mentioned that they would prepare the patients about having music during the surgery before it began, so patients would be relieved even before they are inside the room. Up until now, the act of playing music to patients seemed working well, and the surgeon was planning to play opera music in the future.

4. DISCUSSION

4.1 The acoustic environment and emotional experience

From the results, we found out that sounds related to surgical procedures (PMSDS, CS, STS) were often heard by the patients, and therefore were the main triggers for the emotional experiences. The hypothesis of "Different kinds of sounds that patients heard inside the orthopedic OR may cause different emotions." was supported. When patients were wheeled into the OR, CS already exists and would make them more likely to feel nervous. Beeping sounds and humming sounds are sound together with conversational sounds like preparation for anesthesia and surgery is likely to be the cause of nervousness. In this stage, patients have little knowledge of what is going to happen, and how are their current conditions, so confusion together with an unfamiliar environment will stress them out. After they get used to those sounds, which is in the midway through surgery, they hear STS, which is another trigger for them. curiosity in this stage suggests that they are more uncertain than fearful about the surgery. On the other hand, surgical tools often make sounds like drills and saws, which is rarely linked with high precision works like surgery, so they have the intention to figure out what is happening. When the surgery is about to end, all kinds of sounds are perceived by the patients, so they start to experience boredom and tiredness during the whole process. After surgery, when PMSDS and STS are finally away, they feel more relaxed and relieved due to the contrast effect between the ward and the OR.

Their willingness to listen to music in the OR may have relationship with the sounds they heard, such as STS. Many people chose "Neutral" to represent their emotions which can still be a positive attitude towards accepting music in the OR. The anesthesiologist mentioned in his interview that many people are bored instead of feeling bad when lying on the operating table. So, the future goal of sound-driven design for OR patients could focus on keeping the sound environments interesting for the patients so that they feel more positive or at least neutral emotions, and reduce the abundance of technical OR sounds, if possible, to lower the feeling of uncertainty. Future music intervention may work better before the surgery as we showed that for spinal anesthesia patients, the before-surgery stage elicits the most negative emotions.

4.2 The effect of anesthesia type on patient emotions towards OR sounds

The hypothesis "Anesthesia type affects the emotions of patients before and after orthopedic surgery" is supported. We found that SA patients were found to be more likely to relax after the surgery and compared to GA patients, they know what had happened during the whole time. So, sound designers could target the pre-surgery period to improve the emotional experience of SA patients, which will be further discussed in the Conclusions.

4.3 Music inside the orthopedic OR?

Through the interview, both surgeons and anesthesiologists believed that having music would be possible and might help the patients in some ways from an expert perspective. As the process of surgery may be triggering for the patients, music as a dynamic element, can divert their attention properly and reduce their inner restlessness and boredom. This point of view was also demonstrated through the tryout of one of the surgeons who played music to the patients. The patients' attention was dragged to the music, which let

them ignore the relatively noisy sound environment. Right now, the playlist was made based on the surgeon's preference, due to their longer exposure to sounds compared to patients. But patients were more tolerant of the kinds of music they heard, probably because of their trust in surgeons, or maybe a changing the sounds in their environment would suit their needs just fine.

5. CONCLUSION

It is often assumed that whenever inside the OR, the best for the patients is to let them feel as less as they could, giving them full anesthesia for instance. From the patient's perspective, some might not enjoy the time of being blinded or deaf, not to mention this experience may occur longer-term depression for the patients after surgery. Our research investigated specifically what emotions patients feeling inside orthopedic OR and aimed to understand the effect of sound on emotions. As a result, patients in our study reported that different kinds of sounds had different impacts on them. With further analysis, the interconnection between sounds and emotions were explained and provided the future opportunities for sound-driven design by exemplifying what kinds of sound should be paid attention to, and when should the music intervention be happening. The impact of anesthesia on patients' emotions is yet to be researched, but with the result of this research, it is certain that spinal anesthesia patients' pre-surgery stage requires more attention and care. Certain sounds like of surgical tools may make patients feel curious about the surgery procedure, but it will not hold their attention long. Future design concepts could aim for music that is not only activating but also dynamic, and align with the surgical procedure. In this section, several possible ways of influencing patients' emotional experience inside OR through sound design will be proposed as a conclusion to this study.

5.1 Sound-driven design for the orthopedic OR

The easiest way of avoiding the negative influence of noise would be simply covering up patients' ears. Although it may influence protecting anesthesia awareness [10], silence could sometimes correlate with fear and anger [23]. If patients were to wear headphones during surgery, the types of sound that will be filtered or left must be carefully considered. At a certain point, people who do not hear anything inside the OR are not necessarily more relaxed after the surgery, due to the lack of contrast effect. Also, according to the research, the patients who claimed to not hear anything would want to hear something and were reported to be nervous before the surgery. So simply eliminating sounds will unlikely work well. Moreover, OR staff members heavily depend on surgical sounds for accomplishing a successful surgery [1].

The next solution when it comes to influencing emotions could be having music inside the orthopedic OR. Having music played during the peri-anesthesia nursing period seems like an effective way of influencing patients' emotions. However, it should be clear in which phase the music intervenes, as well as the real audience of the music (staff or patient). Our results showed that the negative feelings occurred the most before the surgery, therefore, music might play a more important role in this stage. As for the type of listeners, it would require more research and observation to reach a conclusion.

This study provides a first step in investigating how patients' emotions change during surgery related to the sound environment and still requires further research in this area. Its results suggest several ways of developing sound design inside OR to improve the experience of patients. The most important conclusion of this study is that the complicated acoustic environment inside OR affects not only medical staff but also patients as well, and how to convert the complex auditory information into a sound that helps patients improve their emotional experience will be a crucial topic in the future.

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