AMERICAN UNIVERSITY OF BEIRUT

PERCEPTION OF MUSIC AND NOISE IN AUBMC OPERATING ROOMS

by
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AN ABSTRACT OF THE THESIS OF

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One of the major concerns in hospital operating rooms (ORs) is the high level of noise during surgery, which has been linked to problems with medical personnel performance, communication, and wellbeing. As such, the presence of noise is also a threat to the overall safety of the OR, including the safety of the patient. The source of the noise includes different types of tools, the clanging of instruments, and, in some cases, the music that surgeons choose to play in the OR. The literature is split as to whether the presence of music contributes to the noise or attenuates its effects. In addition, it is not clear how different factors in the OR, including medical personnel characteristics and surgical conditions, interact with the presence of music and/or noise to affect medical personnel. The overall goal of this research is to analyze the perceived effects of OR noise and music, together with other personnel and environmental factors in the OR, on the performance and attention of medical staff. More specifically, this study aims to 1) measure the noise levels in the ORs at the American University of Beirut Medical Center (AUBMC) and compare them to OSHA standards, 2) conduct interviews with medical personnel to collect data on their impressions of music and noise in the ORs, 3) analyze the link between medical personnel characteristics (e.g., age, gender, experience, specialty, etc.) and their impression of music and noise in the OR, and 4) analyze the link between surgical/environmental conditions and medical personnel's impressions of music and noise. The study will be done in two phases. In Phase I, noise levels inside a representative sample of ORs at AUBMC will be measured using noise sensors. In Phase II, semi structured interviews will be conducted with surgeons, residents, and nurses who are involved in surgical procedures in the AUBMC ORs where noise data was collected. The resulting data will be analyzed in order to establish the link between the levels of noise, the OR environment, and the opinions of medical staff. The results will add to the literature on OR medical personnel safety, as well as increase our understanding of how music and noise interact to bring about performance and attentional problems. The results of this study will also form the basis of a controlled simulator experiment to explore, in more detail, the interaction effects between noise, music, and medical personnel behavior.

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NOMENCLATURE

df	Degree of freedom by SPSS
p	Probability of rejecting the null hypothesis by SPSS “P-value”
F	F statistic for ANOVA
B	Unstandardized regression coefficients
SE	Standard error of the coefficients
β	Standardized regression coefficients
χ^2	Chi-square
n	Sample Size of the participants
η^2	Eta squared (effect size)

CHAPTER I

INTRODUCTION

A. Motivation

The operating room (OR) is an example of a complex system that is safety-critical and time-sensitive. Despite advancements in medicine and biomedical engineering, errors can still occur in the operating room, putting patient safety – and sometimes even medical personnel safety – at risk (Ginsberg et al, 2013). One such major concern in hospital ORs is the high level of noise during surgery. For example, Beyea (2007) detailed a case where a surgeon asked an anesthesiologist to order a spare unit of blood. However, because of the noise in the OR, the anesthesiologist did not hear the surgeon's request. When faced with bleeding and instructed to provide the unit of blood, the anesthesiologist's response was "Which unit of blood?". OR noise is thus not just an inconvenience but a serious threat to patient and medical personnel safety (Katz, 2014).

A sound is described as loud if it exceeds 85 dBA (for comparison, whispering is measured at 30 dBA, and average noises levels are considered to be 40-60 dBA; National Institute of Health (NIH), 2017). The Environmental Protection Agency, the National Institute for Occupational Safety and Health (NIOSH), and the Occupational Safety and Health Administration (OSHA) recommend a maximum of 90 dbA over an 8-hour period. In addition, NIOSH states that noise level shouldn't exceed 40 dbA during the day and 35 dbA during the night (Cordova, 2012). Unfortunately, OR noise levels frequently exceed this limit. In some cases, OR noise levels have reached 120 dBA, comparable to a busy highway (Katz, 2014). Noise levels of around 100 dBA occur 40% of the time during surgeries (Krasht, 2007) and peak levels can reach 131 dBA (Wang et al., 2017).

B. Overview and Background

The impact of high noise levels can be significant for both patients and medical personnel in the OR. At the patient level, loud noise can lead to an increase in blood pressure and heart rate, often considered a threat to patient safety and comfort (Hasfeldt et al, 2014; Katz, 2014; Wang et al, 2017). At the level of the medical personnel, the continuous exposure to noise can be a threat to their physical safety and the overall safety in the OR (Ginsberg et al., 2013).

Despite these problems with noise, reducing the noise levels is challenging, given that most of the noise is generated from necessary equipment and machines. One approach to masking the noise has been to use music in the OR. Proponents of this approach claim that music not only masks some of the noise, but it also has a calming effect, improves motivation, increases accuracy, and reduces stress (e.g., Katz, 2014; Lies and Zhang, 2015; Moorthy et al 2004; Siu et al, 2010; Tseng et al, 2017). On the other hand, music could just be another form of noise that simply creates additional problems. Whether music in the OR is beneficial and should be encouraged, especially in light of the noise already present in the OR, is still up for debate (Moris et al, 2012; Yamasaki, et al, 2014).

CHAPTER II

LITERATURE REVIEW

A. Noise

1. Definition of Noise in the OR

Murthy et al. (1995) define noise as “the wrong sound at the wrong place”; others refer to it as the ‘unwanted sound’ (Blomkvist et al., 2005; Hodge & Thompson, 1990). Given the potentially detrimental effects of noise, researchers have expended considerable effort to measure, study, and analyze noise (Furnham et al 2002), especially in the OR (e.g., Cordova, 2012; Krasht, 2007; Moorthy et al, 2004; Stevenson et al, 2013; Tay et al, 2015). Such studies mainly attempt to investigate noise sources, measure noise levels, identify noise effects, develop ways to avoid or minimize those effects, and establish techniques to assist in reducing noise (e.g., Chen et al., 2012; Holzer et al., 2014; Katz, 2014; Moorthy et al., 2004; Shambo et al., 2015; Stevenson et al., 2013; Tay et al., 2015; Wang et al., 2017).

2. Sources of Noise in the OR

The source of noise in the ORs can be linked to human factors, technology, and equipment used during surgeries. These noise levels can all be measured using dosimeters and sound level meters (Chen et al, 2012; Keller, 2012; Tay et al, 2015; Wang et al, 2017). Major sources of OR noise include essential and extraneous staff conversations, movements in and out of the operating room, and patient care activities such as clinical alarms, checking medical records, and charting and viewing test results (e.g., AORN, 2014; Ginsberg et al, 2013; Katz, 2014; Moorthy et al., 2004; Rogério et al., 2012;). Also, the use of technology – air conditioning, heating systems, smartphones, etc. – has been listed as a source of noise that contributes up to an additional 84 dBA to the background noise (AORN, 2014; Ginsberg et al., 2013; Katz, 2014; Krasht, 2007; Rogério et al., 2012). However, the main contributors to noise in OR were found to be the surgical instruments used during surgeries, which contribute almost 120 dBA (Ginsberg et al., 2013). For example, some of these tools include high speed pneumatic drills, chisels, drills, hammers, and saws (Chen et al, 2012; Holze et al, 2014). Also, vital sign monitors, alarms, ventilators, anesthesia machines, waste management devices, and radiology equipment are sources of ambient noise in OR settings (e.g., AORN, 2014; Ginsberg et al, 2013; Katz, 2014; Moorthy et al, 2004; Rogério et al., 2012). In addition, the clanging and dropping of metal instruments, or the movement of these tools can also lead to noise in the ORs (AORN, 2014; Katz, 2014).

3. Effects of Noise

Several studies have found that, OR noise can be a danger to patient and medical personnel health and safety (Ginsberg et al., 2013; Holzer et al, 2014; Katz, 2014; Shampo et al, 2015; Stevenson et al.,2013; Wang et al, 2017). The focus of this research is on the effects of noise and music on medical personnel, so that will be the focus here. The effects can be divided into those relating to the health of medical personnel and those related to their performance in the OR.

Studies focusing on the health consequences have concluded that OR noise leads to an increase in peripheral vascular residence, blood pressure, heart rate, cardiovascular diseases such as angina pectoris, myocardial infarction, and hypertension (Ginsberg et al., 2013; Katz, 2014). The long-term exposure to noise can lead to problems such as noise-induced hearing loss (NIHL), an irreversible sensorineural condition caused by damage to nerve cells (Ginsberg et al, 2013; Shambo et al, 2015). As an example, according to Willet et al. half of orthopedic surgeons in their study showed significant NIHL. This is due to the exposure to the loud noises of orthopedic surgical tools (Krasht, 2007). Other studies found that a repeated exposure to noise leads to a high probability of damage in nerve cells of the inner ear (Shambo et al., 2015). In addition, noise can lead to other effects such as fatigue, stress, anxiety, headaches, and burn-out (Ginsberg et al., 2013; Katz, 2014; Wang et al., 2017). Noise can arouse the autonomic nervous system and increase stress hormones (Keller et al., 2016).

The possible effects of noise on medical personnel task performance are equally numerous and disturbing. OR noise has been shown to noise can affect the ability to hear audible changes in oxygen saturation levels (Stevenson et al., 2013). In addition, noise can interfere with communication in the OR (Rogério et al, 2012) and lead to decrements in surgeons' concentration and vigilance (Stevenson et al, 2013; Way et al., 2013). For example, noise was found to hinder anesthesia providers from performing cognitive tasks (Shampo et al., 2015; Stevenson et al., 2013). Noise was also found to impair the sensory-motor task performance of medical personnel (Keller et al, 2016). Moreover, the subjective perception of increased noise in the OR was found to be correlated with surgical site infection (Shampo et al., 2013), and 84% of anesthesiologists reported that the noise levels negatively affected their work (Katz, 2014).

B. Music

Research on the effects of music on people's attention and performance has been done in several fields, including sport (Gabana et al., 2015), psychology (Burnset al., 2002), and ORs (e.g. Basea, 2014; Moris, 2012; Siu et al, 2010; Yamasaki, 2014). Results have been mixed; on the one hand, some studies have shown that music has positive effects on behavior, memory, decision making, and attention (Burnset al., 2002; Day et al., 2009; Gabana et al., 2015; Hüttermann, et al., 2015; Mammarella et al., 2007;). One study, for example, showed that music can increase motivation and improve focus (Gabana et al., 2015). On the other hand, others have concluded that music can have damaging effects on attention (Furnham et al., 2002; Reaves et al., 2014). For instance, music has been shown to be particularly detrimental for older adults (Salame et al., 2007) and it has also been linked to decrements in short-term memory performance (Reaves et al, 2014).

1. *Effects of Music in the OR*

Several methods have been used to measure the effects of music on OR medical personnel, including video recording (Weldon et al., 2015) laparoscopic simulators (Conrad et al., 2010; Siu et al, 2010), and standard laboratory psychological stressor tests (Allen et al., 1994). SAGAT -Questionnaire of Situation Awareness Global Assessment Technique- and SWAT -Questionnaire of Subjective Workload Assessment Technique- questionnaires have also been used, where SWAT involves questions as a tool for assessing participant's situation awareness including perception of data, comprehension of meaning, and projection of the near future where SWAT is a tool for investigating the participant's workload which includes 3 indicators time load, mental effort load, and psychological stress load.

The studies about music in ORs mirror overall studies about the effects of music in that it is not clear what the benefits of music are, if any. In some cases, music was found to cause a decrease in auditory processing functions, especially when there is noise (Way et al., 2013). Also, music might cause distraction and reduce the ability of medical staff to coordinate and corporate (Moorthy et al., 2004; Moris and Linos, 2012; Weldon, 2015).

On the other hand, the “Mozart effect” has been identified as the potential of music to reduce state anxiety and mental workload (Tseng et al., 2017). Music can also increase accuracy, concentration, and speed of tasks and improve performance and quality of repair (Allen et al., 1994; Lies & Zhang, 2015; Moorthy et al., 2004; Siu et al, 2014). Moreover, music has been linked to an improvement in performance during stressful tasks (Katz, 2014; R. Lies, 2015; Siu et al, 2014; Tseng et al., 2017) and an improvement in team communication and concentration (e.g., Moris & Linos, 2012; Yamasaki et al., 2014). This study will redress these gaps in our knowledge of music and noise in the OR.

CHAPTER III

METHODOLOGY

In this section we will demonstrate the process that we implemented in our conducted study to collect the data which corresponds to the noise level in AUBMC ORs and the perception of music and noise effect on the medical personnel.

A. Phase I: Collection of Noise Data

The first aim of the study was to establish how loud the noise levels are in AUBMC ORs. Operations in all branches of medicine excluding robotics surgeries were examined including pediatrics, plastic, general, vascular, urology, ophthalmology, orthopedics, otolaryngology, open heart surgery, and neurosurgery. The reason behind excluding the robotics surgeries from this study is because none of the recruited participants was from this specialty. To this end, noise levels were measured using an application called “Sound Affects” installed on iPad that records noise decibel levels. The application uses the built-in microphone of the iPad so it accounts for the relative loudness perceived by the human ear which known as A-weighting value. This was developed by the company “Memac Ogilvy” based on technical requirements from the Patient Affairs Unit at AUBMC. The iPads were installed inside all ten ORs of AUBMC for a 24 h period from March 13 till March 27. Readings were collected during weekdays only so as to guarantee surgical action within the room. Note that audio was not recorded by this application, meaning that there is no risk at all of any conversations being replayed. The iPad was placed inside a thin plastic bag in a corner of the operating theater. The application recorded noise levels every 5 seconds, from which the peak and the average noise levels during each surgery were obtained. In total, 134 surgeries were measured.

Once all of the data was collected, OR schedules were examined to identify operations occurring within the sampled intervals. Appropriate permission was obtained from the OR administration to view these records. These schedules provide information on the nature and duration of each surgery. These schedules are normally quite accurate and based on the clock in each OR. The iPad's clock was synchronized to this clock as well.

Using the data obtained from the sound level meter and the surgery times, sound levels for each surgery were calculated. An A-weighted equivalent continuous sound level (L_{eq}) was calculated by averaging over the time of the particular surgery. In other words, the total average sound level (in dB) was calculated by averaging all the sound levels recorded during the surgery.

B. Phase II: Interviews with Medical Personnel

1. Participants

A total of 38 participants were recruited for this study. They are physicians, nurses, and residents who were involved in surgical procedures. This gives a Pearson correlation coefficient of 0.33 between surgery time and average noise level, with a Type I error rate of 0.05, Type II error rate of 0.2. The only inclusion criteria were that participants must be current nurses, physicians, or residents at AUBMC who participated in surgeries during the same day of the interview. All the nurses who participate in this study are registered nurses. For them, specialty was assigned based on the type of surgery that they were interviewed for. Table 1 shows the demographic of participants.

Table 1. Demographics of participants

Demographics	Number
Gender	
Male	26
Female	12
Age	
Under 30	15
30 – 39	12
40 – 49	4
50 or above	7
Role	
Nurse	19
Resident	8
Surgeon	11
Specialty	
Pediatrics	2
Neurosurgery	9
ENT	5
Plastic	4
General	5
Ophthalmology	6
Orthopedics	3
Vascular	1
Open Heart	1
Urology	2

The interviews took place on the same day that the participants have been involved in a surgery in the OR. The interviews were done in the physicians' lounge on the second floor of the main hospital and in the physicians' and nurses' lounge of the OR. These locations were selected as they are both private and quiet. Care was taken to protect the interviewee's privacy; the room was only used if empty. Otherwise, the interview was halted until the room is clear.

Participants were recruited by means of an email that was sent by the IT Academic Core Processes and Systems (ACPS) to a random sample of the medical personnel at AUBMC. The email list was obtained by the HRPP/IRB office. Another reminder email was sent two weeks after the original email. Potential participants were asked to reply to a member of the research team to express their willingness to participate. A member of the research team then got in touch to schedule an experiment session. One reminder to these participants was sent the day before the interview.

2. *Procedure*

When participants first arrived at the interview location, they were asked to read and sign the consent form. They were then briefed about the study objectives. Participants were informed that their participation is completely voluntary, and they have the right to not answer any question or to stop the interview whenever they want. Also, they were informed that the interview is going to be recorded. The interviewer then turned on the recorder and went through the interview questions. The interview took around 20 minutes. No data was collected from the medical personnel prior to the interview. When participants preferred not to have the interview recorded, the interviewer took written notes. The interview questions can be seen in Appendix A (nurse version), Appendix B (resident version), and Appendix C (surgeon version). The reason different versions were developed is because each category of medical personnel has a different role to play in the OR and in the selection (or non-selection) of the music.

In general, the interview is divided into three parts. The first asks for standard demographic information, such as the participant’s age and years at AUBMC. The second part of the interview asks participants to provide information about the surgery that they were involved in on that day, including ratings of the difficulty of the surgery, whether music was played, how loud they thought the noise levels were, etc. Finally, the third part of the interview targets participants' overall views of noise and music in the OR, based on their experience.

All the recorded data was stored on a password-protected computer that only the members of the research team have access to. All data was also de-identified and will be stored for two years before being securely destroyed.

CHAPTER IV

RESULTS AND FINDINGS

One-way analysis of Variance (ANOVA), Kruskal-Wallis H test, regression, and correlation were used for the analysis. The Kruskal-Wallis H test was selected in place of the one-way ANOVA to determine the differences between groups because some of the ordinal interview data collected was significantly non-normal. All the analyses were done using Excel and SPSS v.25. The significance level alpha (α) was set at 0.05 for all analyses. All the rating effects are on a scale from 1 (very negatively) to 5 (very positively).

A. Objective I

Table 2 and Figure 1 summarizes the results for surgical noise levels presented by type of surgery. Each result thus represents an average over multiple surgeries, in most cases in more than one OR. The categories in the table are ordered by the decreasing (L_{eq}).

Table 2. Average Leq ordered by decreasing average and range for surgeries by category.

Division	Number of Surgeries Included	$L_{eq}(dB(A))$	$dB(A))$ Range (Min – Max)	Number of rooms covered
Orthopedics	24	45	32.7-51.8	2

Open Heart	8	43.4	40.1-50.2	1
Plastic	8	42.5	37.2-47.5	1
Otolaryngology (ENT)	14	41.2	33.3-46.6	1
General	19	41.1	34.6-48.4	5
Pediatrics	7	40.6	29.4-52.2	1
Vascular	8	39.9	29.4-45.7	2
Ophthalmology	24	38.7	30.7-42.9	1
Urology	7	38.7	28.8-46.1	2
Neurosurgery	15	36.8	31.9-42.5	1

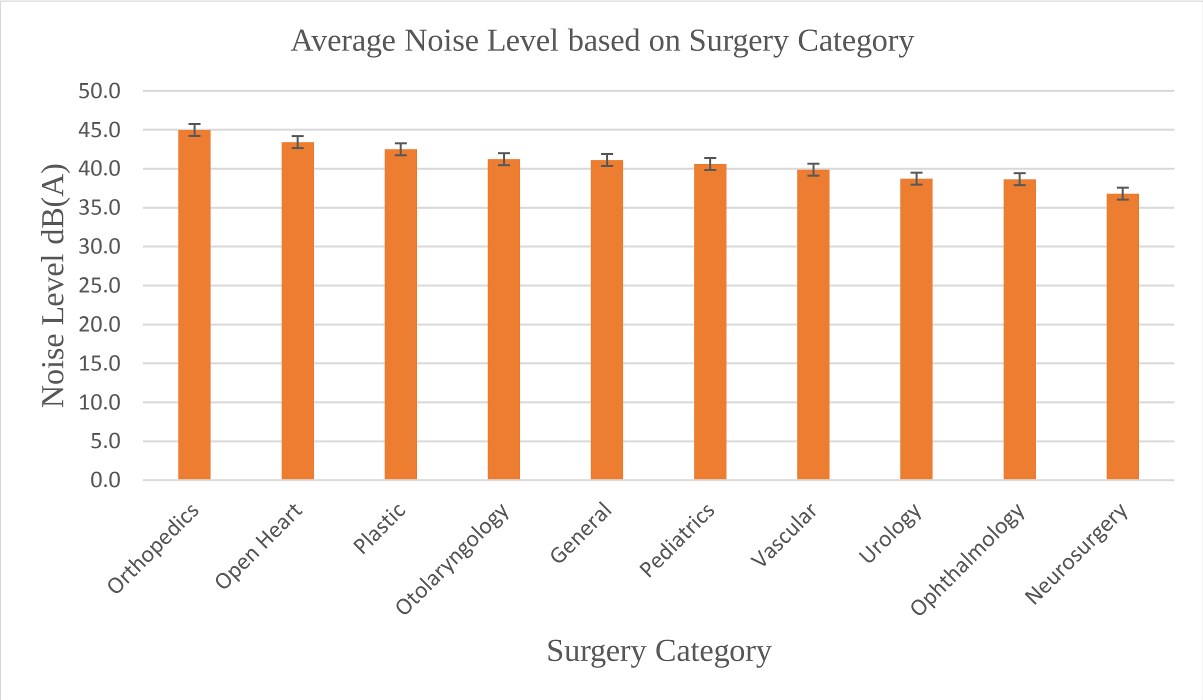

Figure 1. Average noise level based on surgery category

Surgeries were classified by time. Since there was no specific convention in the literature to divide the time of the day for ORs, simple division into four segments was used as seen in Table 3. The classification of these surgeries based on time of the day is in Table 4.

Table 3. Division of the time of the day

Hours	Time of the Day
06:00 am – 11:59 am	Morning
12:00 pm – 05:00 pm	Afternoon
05:01 pm – 08:00 pm	Evening
08:01 pm – 05:59 am	Night

Table 4. Classification of surgeries based on time of the day

Time of the day	Number of surgeries
Morning	21
Afternoon	13
Evening	2
Night	2

B. Objective II

The target was to conduct interviews for medical personnel who are involved in as many of these surgeries as possible. The final count of 38 interviews conducted spanned 10 specialties. Each of these interviews corresponds to a different actual surgery, with one exception, where two nurses were interviewed who had been in the same exact OR during a neurosurgery. Table 5 summarizes the number of interviews for each surgical specialty.

Table 5. Summary of interviews per surgery category

Surgery Category	Number of interviews
Neurosurgery	9
Ophthalmology	6
Otolaryngology (ENT)	5
General	4
Plastic	4
Orthopedics	3
Urology	2
Pediatrics	2
Open Heart	2
Vascular	1

Table 6 summarizes the responses of participants regarding the presence of noise or music during these surgeries. Out of the 38 participants, only 18 claimed that there was noise during the surgery and only 10 said that music had been played. Table 7 also shows participants' ratings of the levels of music and noise (low, moderate, high).

Table 6. Summary of the presence of noise or music during surgery

Response	Number
Noise Exists	
Yes	18
No	20
Music Played	
Yes	10
No	28

Table 7. Summary of the noise and music level during surgery

Response	Number
Noise Level	
Low	4
Moderate	10
High	4

C. Objective III

Table 8 summarizes the statistical techniques that were done in order to achieve Objective III, which is to determine the effects of noise and music on performance, communication, and concentration. To that end, multiple linear regression and Kruskal-Wallis H tests were done. For the multiple linear regression models, since some of the variables used are categorical, $n - 1$ dummy variables were added for each category to represent this distribution over the category, where n is the number of categories per variable. Also, for the ANOVA and Kruskal-Wallis H test, only the categories with more than three responses were included.

Table 8. Summary of the analysis techniques for Objective III

Type of Study	Dependent Variable (scale: 1-5)	Independent Variables
Regression	Ratings of effects of noise on 1. Performance 2. Communication 3. Concentration Ratings of effects of music on 1. Performance 2. Communication 3. Concentration	1. Age [1] 2. Years of Experience [2] 3. Gender [M / F] 4. Noise Level [dBA] 5. Music Level[3]
Kruskal-Wallis H test	Ratings of effects of noise on 1. Performance 2. Communication 3. Concentration Ratings of effects of music on 1. Performance 2. Communication 3. Concentration	1. Role[4] 2. Specialty

[1] Scale: Under 30, 30-39, 40-49, 50 or above.

[2] Scale: Under 5, 5-9, above 10.

[3] Low, Medium, High

4 Nurses, Surgeons, and Residents.

1. Effects of Noise

Three multiple linear regression models were run to predict the effect of noise level (dBA), music level, age, and years of experience on medical personnel's perception on the effects of noise. More specifically, one model was created for each of the reported ratings of the effects of noise on performance, communication, and concentration, respectively. For the three models, the assumption of normality was met and there was independence of residuals as assessed by a Durbin-Watson statistic. Table 9 summarizes the variables used to predict the effect of noise level (dBA), music level, age, and years of experience on medical personnel's perception on the effects of noise.

Table 9. Summary of the variables used during the regression testing modal for noise effect

Variable	Interpretation	Value
Noise Level	Noise level (dB) as measured by the iPad	dB value from the iPad
Music Level Zero	Music was not played during the surgery	1 if there was no music, otherwise 0
Music Level Low	Music was played with a low level during the surgery (from the survey results)	1 if music level is low, otherwise 0
Music Level Moderate	Music was played with a moderate level during the surgery (from the survey results)	1 if music level is moderate, otherwise 0
Gender	Gender	1 if male, 0 if female
Age Under 30	Age of the participant	1 if age under 30, otherwise 0
Age 30 – 39	Age of the participant	1 if age between 30 and 39, otherwise 0
Age 40 – 49	Age of the participant	1 if age between 40 and 49, otherwise 0

Years of Experience Under 5	Years of experience of the participant	1 if years of experience under 5, otherwise 0
Years of Experience 5 - 9	Years of experience of the participant	1 if years of experience between 5 and 9, otherwise 0

A multiple linear regression model failed to significantly predict the effect on noise on performance, F (10, 14) = 0.797, p = 0.635, $adj\ R\ square$ 0.372. None of the variables contributed significantly to the prediction. On the other hand, a multiple linear regression model significantly predicted the effect of noise on communication, F (10, 14) = 2.804, p = 0.038 < 0.05, $adj\ R\ square$ 0.429. Music level and age significantly added to the prediction, p < 0.05. All the coefficients for the music level are strictly positive which suggests that the effects of noise on communication increase as the music level increases. With regards to age, only those who are younger than 40 are affected by the noise because the coefficient is negative and so noise effect will increase in the negative direction. The rating effect of noise on communication is from 1 to 5 with 1 being very negatively and 5 very positively, this means that music doesn’t interfere with communication and as the age increases, noise effect on communication between medical staff is less critical. A multiple linear regression model also failed to significantly predict the effect of noise on concentration, F (10, 14) = 0.858, p = 0.588, $adj\ R\ square$ 0.4. None of the variables contributed significantly to the prediction.

According to these models, the effect of noise on performance, communication, and concentration are according to the following functions:

$$Performance = 1.811 + (0.013 * Noise\ Level) + (0.481 * MusicLevelZero) + (0.772 * MusicLevelLow) + (0.492 * MusicLevelModerate) + 0(.048 * Gender) - (0.571 * AgeUnder30) - (0.325 * Age30To39) - (0.455 * Age40To49) + (0.197 * YearsOfExperienceUnder5) + (0.533 * YearsOfExperience5To9)$$

$$Communication = 0.462 + (0.034 * Noise\ Level) + (1.112 * MusicLevelZero) + (1.484 * MusicLevelLow) + (1.873 * MusicLevelModerate) - (0.186 * Gender) - (0.853 * AgeUnder30) - (1.061 * Age30To39) + (0.011 * Age40To49) + (0.273 * YearsOfExperienceUnder5) + (0.263 * YearsOfExperience5To9)$$

$$Concentration = 1.190 + (0.044 * Noise\ Level) - (0.599 * MusicLevelZero) - (0.630 * MusicLevelLow) + (0.482 * MusicLevelModerate) - (0.296 * Gender) + (0.643 * AgeUnder30) + (0.373 * Age30To39) + (0.648 * Age40To49) - (0.258 * YearsOfExperienceUnder5) - (0.226 * YearsOfExperience5To9)$$

Table 10 summarizes the three multiple linear regression models for the effect of noise on performance, communication, and concentration from noise level, music level, age, and years of experience.

Table 10. Multiple linear regression model summaries

Model	Sample size	p-value
Effect of noise on performance	25	0.0635
Effect of noise on communication	25	0.0588

Effect of noise on concentration	25	0.038

Table 11 summarizes the coefficients of the three multiple linear regression models for the effect of noise on performance, communication, and concentration from noise level, music level, age, and years of experience.

Table 11. Regression coefficients and standard errors

Model	Variable	B	SE_B	β
Effect of noise on performance	(Constant)	1.811	1.043	
	Noise Level as Measured	.013	.023	.168
	Music Level (Zero)	.481	.541	.463
	Music Level (Low)	.772	.602	.606
	Music Level (Moderate)	.492	.799	.286
	Gender	.048	.259	.048
	Age (Under30)	-.571	.552	-.588
	Age (30 - 39)	-.325	.365	-.313
	Age (40 - 49)	-.455	.449	-.264
	Years of Experience (Under 5)	.197	.520	.203
	Years of Experience (5 - 9)	.533	.584	.419
Effect of noise on communication	(Constant)	.462	1.010	
	Noise Level as Measured	.034	.022	.327
	Music Level (Zero)	1.112	.524	.799
	Music Level (Low)	1.484	.583	.871
	Music Level (Moderate)	1.873	.774	.813
	Gender	-.186	.251	-.139

	Age (Under30)	-.853	.534	-.655
	Age (30 - 39)	-1.061	.354	-.762
	Age (40 - 49)	.011	.435	.005
	Years of Experience (Under 5)	.237	.503	.182
	Years of Experience (5 - 9)	.263	.566	.154
Effect of noise on concentration	(Constant)	1.190	1.405	
	Noise Level as Measured	.044	.030	.412
	Music Level (Zero)	-.599	.730	-.422
	Music Level (Low)	-.630	.811	-.362
	Music Level (Moderate)	.482	1.077	.205
	Gender	-.296	.350	-.217
	Age (Under30)	.642	.744	.483
	Age (30 - 39)	.373	.492	.262
	Age (40 - 49)	.648	.606	.276
	Years of Experience (Under 5)	-.258	.700	-.194
	Years of Experience (5 - 9)	-.226	.787	-.130

Note. B = Unstandardized regression coefficients; SE_B= Standard error of the coefficients; β = Standardized coefficients.

A Kruskal-Wallis H tests was conducted to determine if there are differences between nurses, residents, and physicians in terms of the effects of noise on performance, communication, and concentration. Values in parentheses are mean unless otherwise stated. Effect of noise on performance, communication, and concentration scores were not similar for all roles, as assessed by visual inspection of a boxplot. Effect of noise on performance decreased from the surgeons (3.00), to nurse (2.50), and then increased to residents (3.00), in that order, but the difference between these role groups was not statistically significant, $\chi^2(2)$ = 4.734, p = .094. Effect of noise on communication decreased from the surgeons (2.5), to nurse (2.21), and then increased to residents (2.5), in that order, but the difference between these roles was not statistically significant, $\chi^2(2)$ = .96, p = .619. Effect of noise on concentration decreased from the nurses (2.5), to surgeons (2.25), and then increased to residents (2.5), in that order, but the difference between these roles was not statistically significant, $\chi^2(2)$ = .794, p = .672. Figure 1 shows the mean value of noise effect on performance, communication, and concentration based on role.

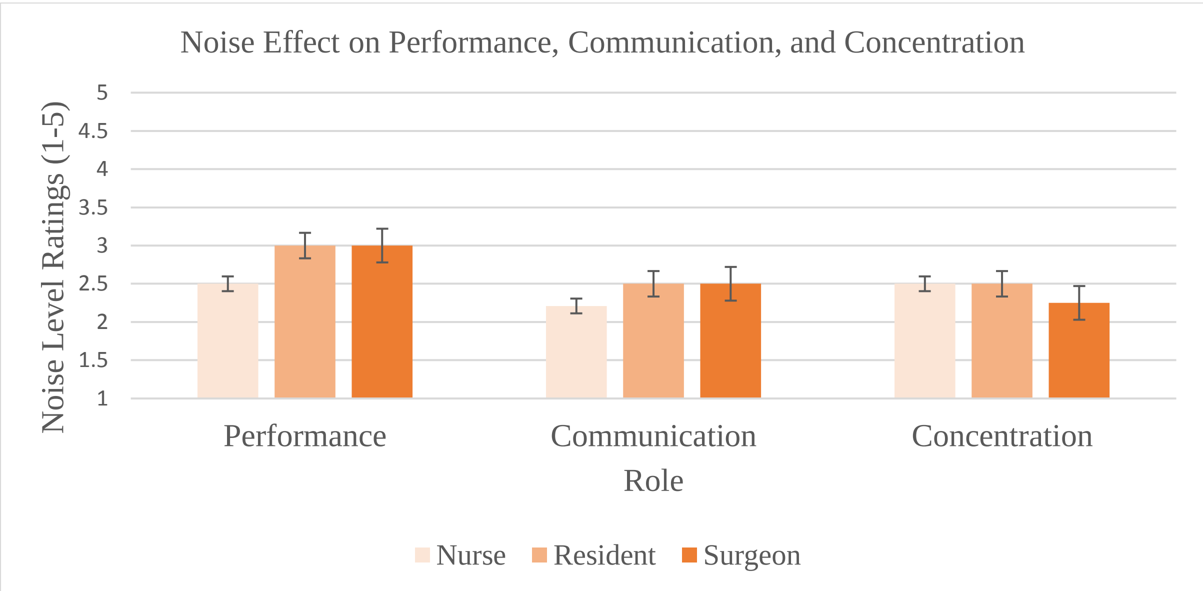

Figure 2. Noise effect on performance, communication, and concentration based on role

Another Kruskal-Wallis H test was conducted to determine if there are any differences in the effects of noise on performance, communication, and concentration between medical personnel of different specialties. The effect of noise on performance decreased from pediatrics (3.50), to ophthalmology (2.40), and then increased to neurosurgery (2.67), but the difference between these specialties was not statistically significant, $\chi^2(9)$ = 9.131, p = .425. Effect of noise on communication decreased from pediatrics (2.50), to ophthalmology (2.20), and then to neurosurgery (2.00), but the difference between these specialties was not statistically significant, $\chi^2(9)$ = .6.688, p = .670. Effect of noise on concentration decreased from ophthalmology (2.60), to pediatrics (1.50), and then increased to neurosurgery (2.17). Effect of noise on concentration was significantly different between different surgery categories, $\chi^2(9)$ = 14.474, p = .043. Figures 3, 4, and 5 show the mean value of noise effect on performance, communication, and concentration based on specialty.

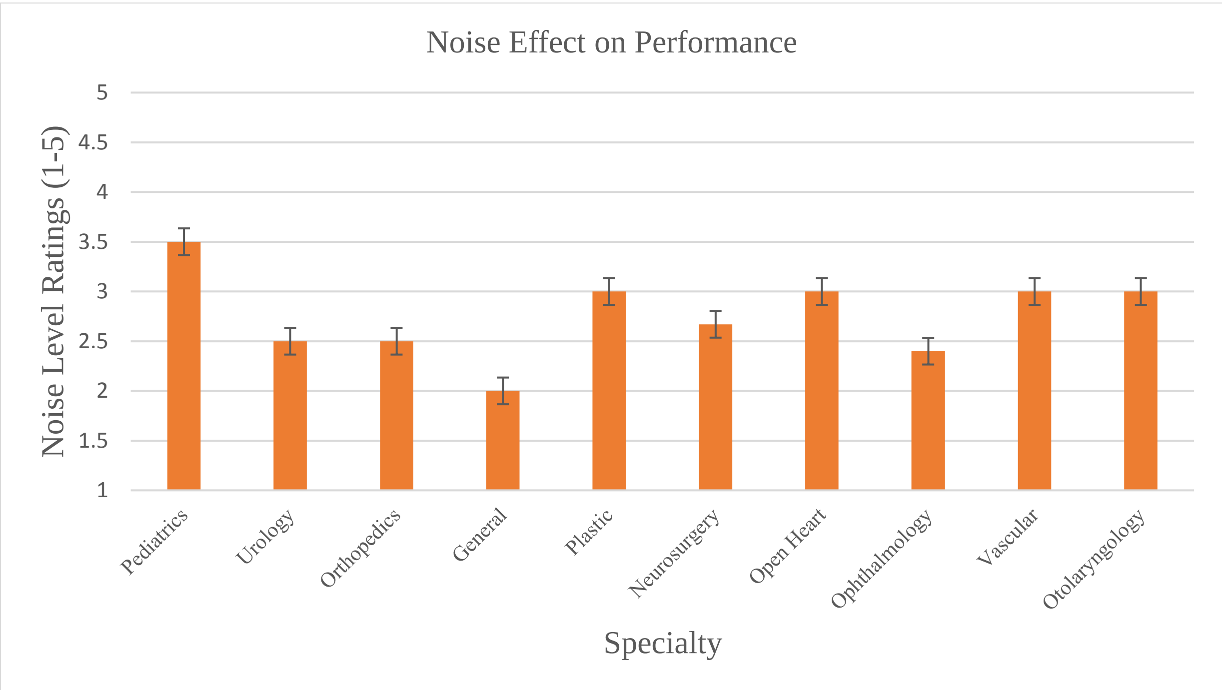

Figure 3. Noise effect on performance based on specialty

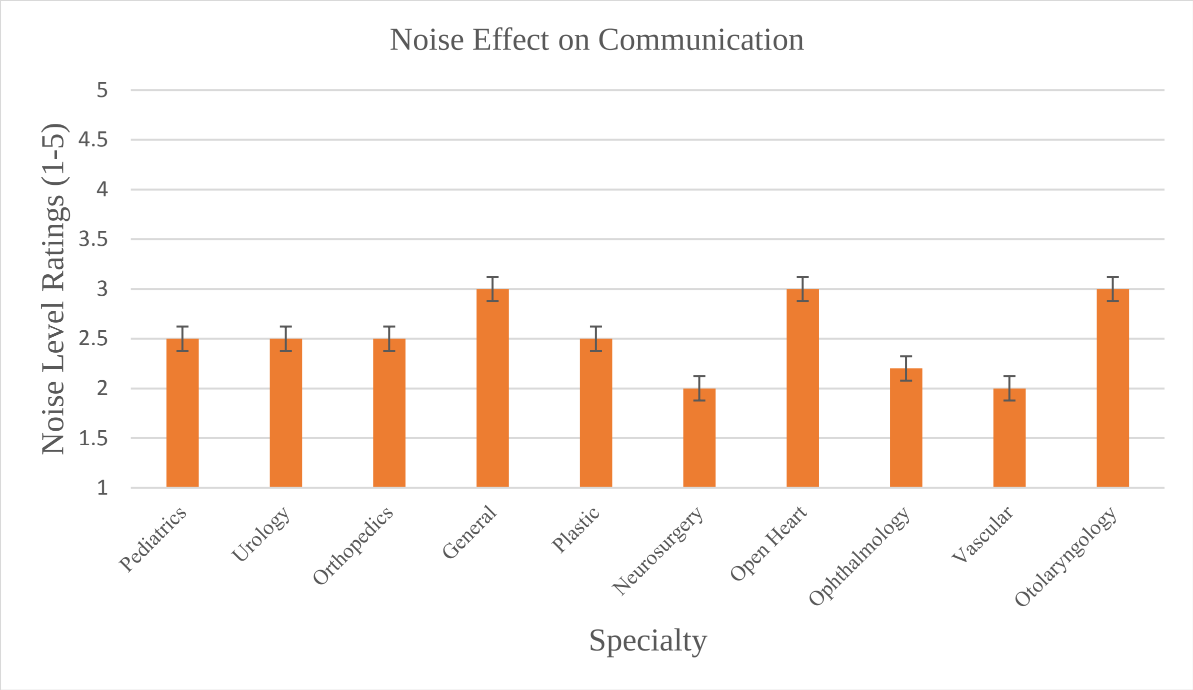

Figure 4. Noise effect on communication based on specialty

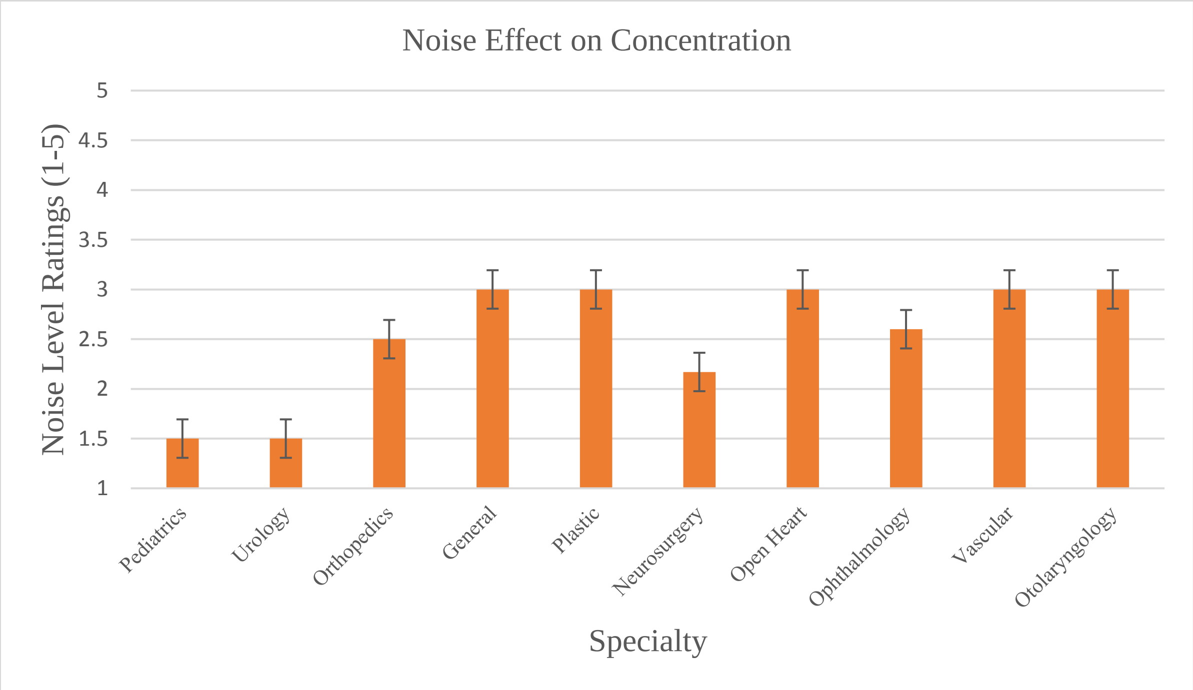

Figure 5. Noise effect on concentration based on specialty

2. *Effects of Music*

Another three multiple linear regression models were run to predict the effect of noise level (dB(A)), music level, age, and years of experience on medical personnel's perception on the effects of music. More specifically, one model was created for each of the reported ratings of the effects of music on performance, communication, and concentration, respectively. For the three models, the assumption of normality was met and there was independence of residuals as assessed by a Durbin-Watson statistic.

Table 12 summarizes the variables used to predict the effect of noise level (dBA), music level, age, and years of experience on medical personnel's perception on the effects of music.

Table 12. Summary of the variables used during the regression testing modal for noise effect

Variable	Interpretation	Value
Noise Level	Noise level (dB) as measured by the iPad	dB value from the iPad
Music Level Low	Music was played with a low level during the surgery (from the survey results)	1 if music level is low, otherwise 0
Music Level Moderate	Music was played with a moderate level during the surgery (from the survey results)	1 if music level is moderate, otherwise 0
Gender	Gender	1 if male, 0 if female
Age Under 30	Age of the participant	1 if age under 30, otherwise 0
Age 30 – 39	Age of the participant	1 if age between 30 and 39, otherwise 0
Age 40 – 49	Age of the participant	1 if age between 40 and 49, otherwise 0
Years of Experience Under 5	Years of experience of the participant	1 if years of experience under 5, otherwise 0
Years of Experience 5 - 9	Years of experience of the participant	1 if years of experience between 5 and 9, otherwise 0

A multiple regression model failed to significantly predict the effect of music on performance, F (9, 4) = 0.797, p = 0.332, $adj\ R\ square$ 0.187. None of the variables contributed significantly to the prediction. Also, a multiple regression model failed to significantly predict the effect of music on communication, F (9, 4) = 2.368, p = 0.211, $adj\ R\ square$ 0.486. None of the variables contributed significantly to the prediction. In addition, a multiple regression model failed to significantly predict the effect of music on concentration, F (9, 4) = 2.014, p = 0.261, $adj\ R\ square$ 0.413. None of the variables contributed significantly to the prediction.

According to these models, the effect of music on performance, communication, and concentration are according to the following functions:

$$
\begin{aligned}
Performance &= 10.196 - (0.155 * Noise\ Level) + (0.479 * MusicLevelLow) \\
&+ (2.322 * MusicLevelModerate) - (1.121 * Gender) \\
&+ (0.912 * AgeUnder30) - (0.432 * Age30To39) + (0.721 \\
&* Age40To49) - (0.904 * YearsOfExperienceUnder5) \\
&- (1.058 * YearsOfExperience5To9)
\end{aligned}
$$

$$
\begin{aligned}
Communication &= 9.239 - (0.156 * Noise\ Level) + (1.479 * MusicLevelLow) \\
&+ (3.726 * MusicLevelModerate) - (1.122 * Gender) \\
&+ (0.513 * AgeUnder30) - (0.435 * Age30To39) + (0.723 \\
&* Age40To49) - (0.505 * YearsOfExperienceUnder5) \\
&- (1.862 * YearsOfExperience5To9)
\end{aligned}
$$

$$
\begin{aligned}
Concentration &= 10.196 - (0.155 * Noise\ Level) + (0.479 * MusicLevelLow) \\
&+ (3.322 * MusicLevelModerate) - (1.121 * Gender) \\
&+ (0.912 * AgeUnder30) - (0.432 * Age30To39) + (0.721 \\
&* Age40To49) - (0.904 * YearsOfExperienceUnder5) \\
&- (2.058 * YearsOfExperience5To9)
\end{aligned}
$$

Table 13 summarizes the three multiple linear regression models for the effect of music on performance, communication, and concentration from noise level, music level, age, and years of experience.

Table 13. Multiple linear regression model summaries

Model	Sample size	p-value
Effect of music on performance	14	0.332
Effect of music on communication	14	0.211
Effect of music on concentration	14	0.261

Table 14 summarizes the coefficients of the three multiple linear regression models for the effect of music on performance, communication, and concentration from noise level, music level, age, and years of experience.

Table 14. Regression coefficients and standard errors

Model	Variable	B	SE_B	β
Effect of music on performance	(Constant)	10.196	3.546	
	Noise Level as Measured	-.155	.082	-.650
	Music Level (Low)	.479	.989	.287
	Music Level (Moderate)	2.322	1.238	1.313
	Gender	-1.121	.750	-.491
	Age (Under30)	.912	1.072	.547
	Age (30 - 39)	-.432	.867	-.267
	Age (40 - 49)	.721	.996	.233
	Years of Experience (Under 5)	-.904	1.071	-.464
	Years of Experience (5 - 9)	-1.058	.890	-.655

Effect of music on communication	(Constant)	9.239	3.189	
	Noise Level as Measured	-.156	.074	-.578
	Music Level (Low)	1.479	.889	.784
	Music Level (Moderate)	3.726	1.114	1.863
	Gender	-1.122	.674	-.435
	Age (Under30)	.513	.964	.272
	Age (30 - 39)	-.435	.779	-.238
	Age (40 - 49)	.723	.895	.206
	Years of Experience (Under 5)	-.505	.963	-.229
	Years of Experience (5 - 9)	-1.862	.801	-1.020
Effect of music on concentration	(Constant)	10.196	3.546	
	Noise Level as Measured	-.155	.082	-.552
	Music Level (Low)	.479	.989	.244
	Music Level (Moderate)	3.322	1.238	1.597
	Gender	-1.121	.750	-.418
	Age (Under30)	.912	1.072	.465
	Age (30 - 39)	-.432	.867	-.227
	Age (40 - 49)	.721	.996	.198
	Years of Experience (Under 5)	-.904	1.071	-.395
	Years of Experience (5 - 9)	-2.058	.890	-1.084

Note. B = Unstandardized regression coefficients; SE_B= Standard error of the coefficients; β = Standardized coefficients.

Also, one Kruskal-Wallis H test was conducted to determine if there are differences between nurses, residents, and physicians in terms of the effects of music on performance, communication, and concentration. Values are mean ranks unless otherwise stated. Effect of music on performance, communication, and concentration scores were not similar for all roles and specialties, as assessed by visual inspection of a boxplot. Effect of music on performance decreased from the surgeons (4.17), to nurse (3.25), and then increased to residents (4.25), in that order, but the difference between these roles was not statistically significant, $\chi^2(2) = 3.814$, $p = .148$. Effect of music on communication decreased from the surgeons (3.83), to nurse (3.00), and then increased to residents (3.75), in that order, but the difference between these roles was not statistically significant, $\chi^2(2) = 2.337$, $p = .311$. Effect of music on concentration decreased from the surgeons (4.00), to nurse (3.25), and then increased to residents (4.00), in that order, but the difference between these roles was not statistically significant, $\chi^2(2) = 1.996$, $p = .369$. Figure 6 shows the mean value of music effect on performance, communication, and concentration based on role.

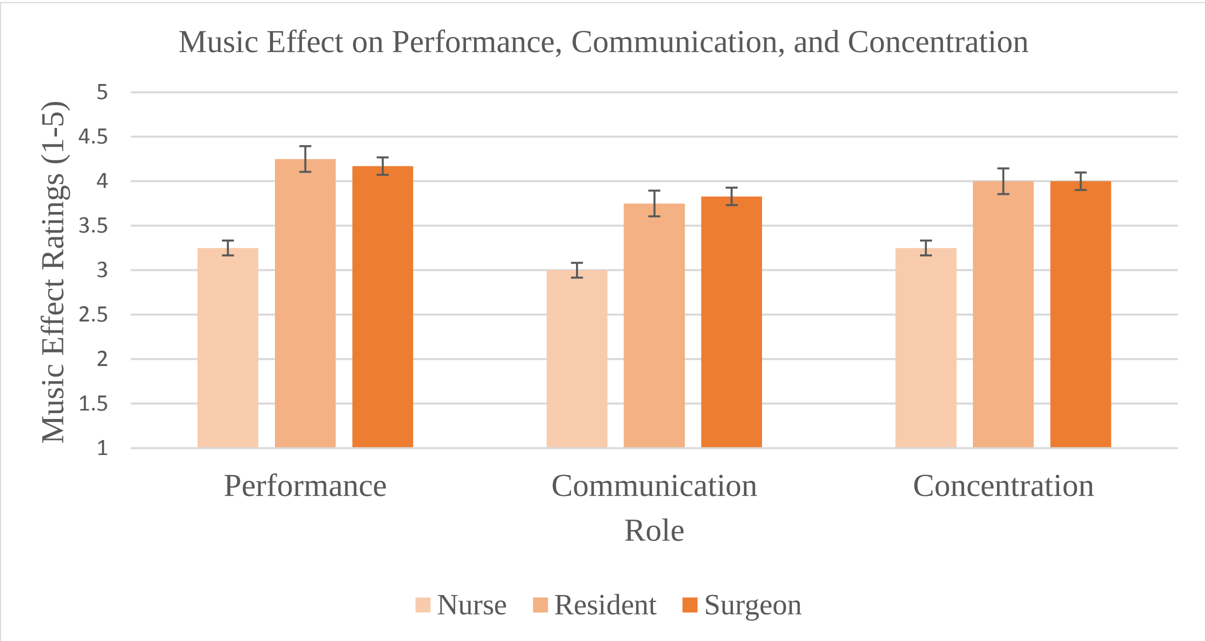

Figure 6. Music effect on performance, communication, and concentration based on role

Another Kruskal-Wallis H test was conducted to determine if there are any differences in the effects of music on performance, communication, and concentration between medical personnel of different specialties. Effect of music on performance decreased from general (4.5), to neurosurgery (3.75), and then increased to plastic (4.00), in that order, but the difference between these specialty groups was not statistically significant, $\chi^2(9) = 2.526$, $p = .773$. Effect of music on communication decreased from plastic (4.00) to general (3.5), and to neurosurgery (3.50) in that order, but the difference between these specialty groups was not statistically significant, $\chi^2(9) = 1.492$, $p = .914$. Effect of music on concentration decreased from general (4.0), to neurosurgery (3.50), and then increased to plastic (4.00), in that order, but the difference between these specialty groups was not statistically significant, $\chi^2(9) = 1.412$, $p = .923$. Figure 7, 8, and 9 show the effect of music on performance, communication, and concentration based on specialty.

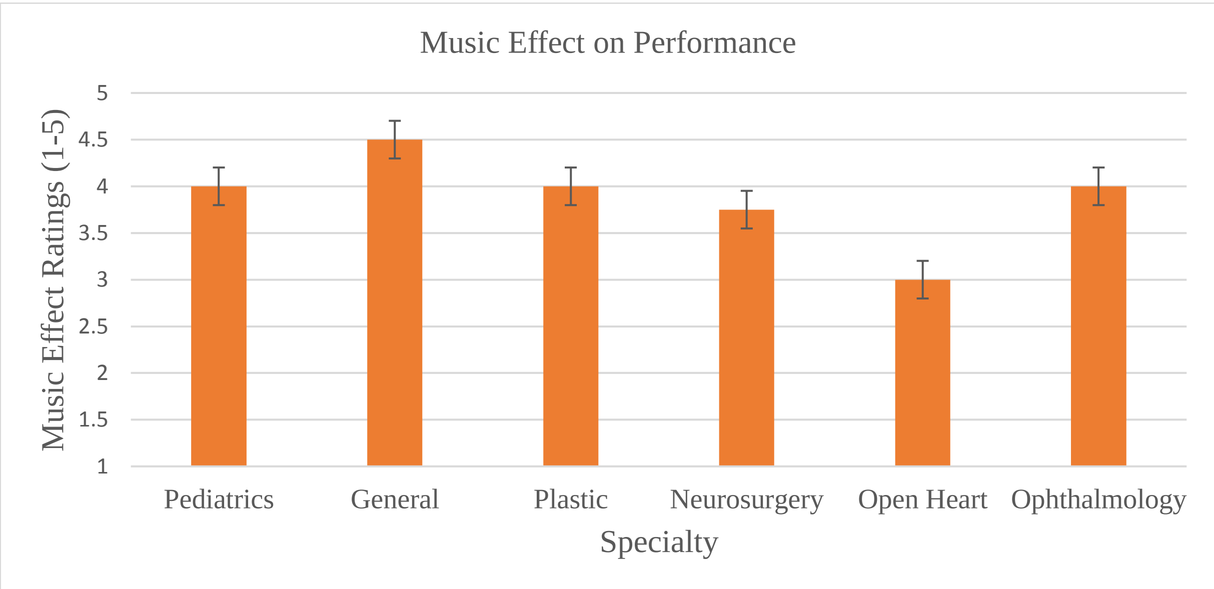

Figure 7. Music effect on performance based on specialty

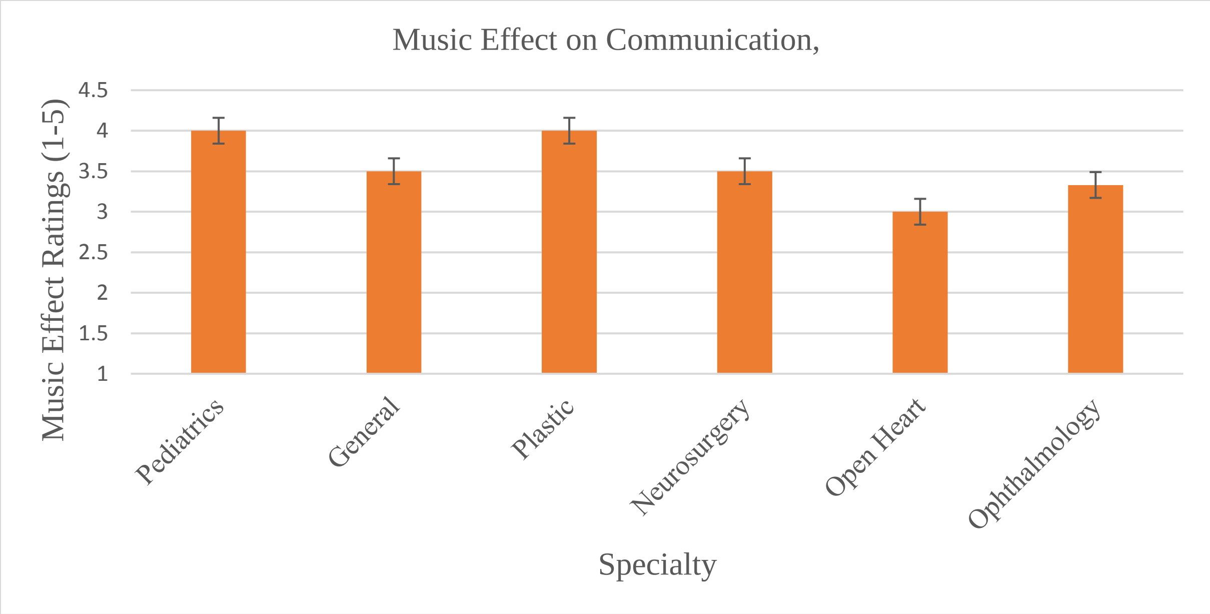

Figure 8. Music effect on communication based on specialty

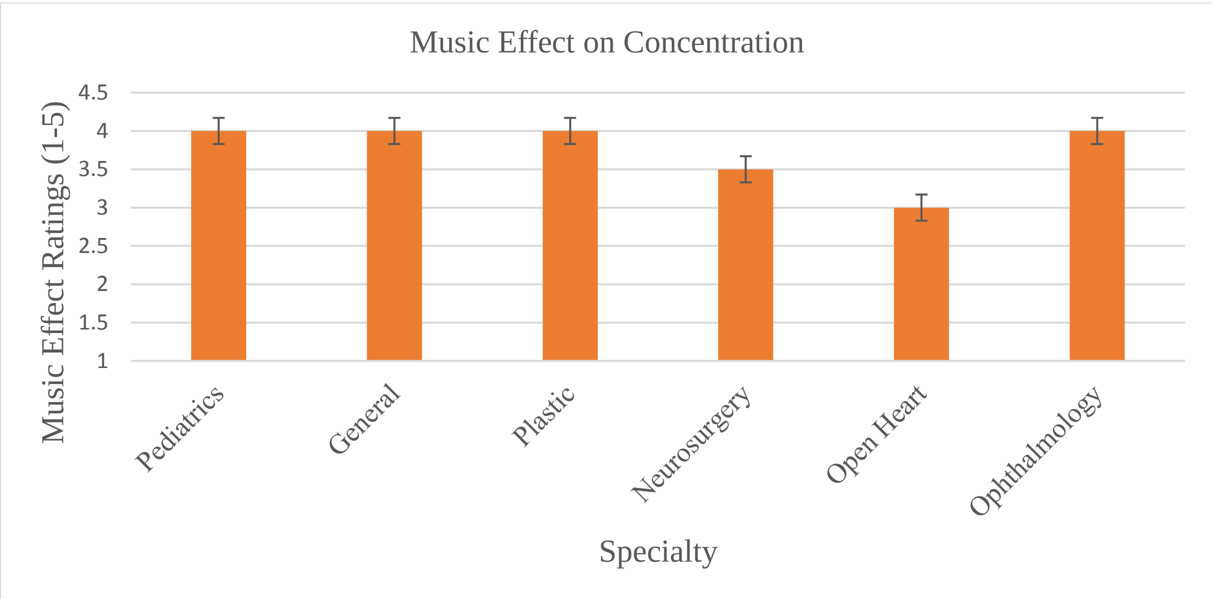

Figure 9. Music effect on concentration based on specialty

D. Objective IV

Table 15 summarizes the statistical techniques that were done in order to achieve Objective IV, which is to determine the effects of music on performance, communication, and concentration and to study the noise level based on surgery type, surgery time, and surgery difficulty.

Table 15. Summary of the analysis techniques for Objective IV

Type of Study	Dependent Variable (scale: 1-5)	Independent Variables
ANOVA	1. Average Noise Level	1. Type of Surgery [o] 2. Difficulty of Surgery [1] 3. Time of Surgery [2]
Kruskal-Wallis H test	Ratings of effects of music on 1. Performance 2. Communication 3. Concentration	1. Music Type

[o] pediatrics, plastic, general, vascular, urology, ophthalmology, orthopedics, otolaryngology, open heart surgery, and neurosurgery.

[1] Scale from 1-5.

[2] Morning (06:00 am – 11:59 am), After Noon (12:00 pm – 05:00 pm), Evening (05:01 pm – 08:00 pm), and Night (08:01 pm – 05:59 am).

1. Noise Level

To test the effect of surgical / environmental characteristics on the noise level, single linear regression and ANOVA analyses were done. A one-way ANOVA was conducted to determine if the average noise level was different for surgeries with different types, difficulties, and times. There were no outliers, data was normally distributed for each group ($p > 0.05$), and there was homogeneity of variance ($p = 0.067$). Data is presented as mean $\pm$ standard deviation.

Noise level was significantly different between different surgery categories, F (7, 28) = 4.006, p = .004, η^2 = 0.734. Tukey post hoc analysis revealed that the increase from neurosurgery to orthopedics (9.68, 95% CI (19.35 to 0.02)) was statistically significant (*p* = .049), as well as the increase from urology to orthopedics (14.72, 95% CI (27.95 to 1.48), *p* = 0.021), but no other group differences were statistically significant. Figure 10 shows the mean value of noise level based on surgery category for the surgeries that we did interview for.

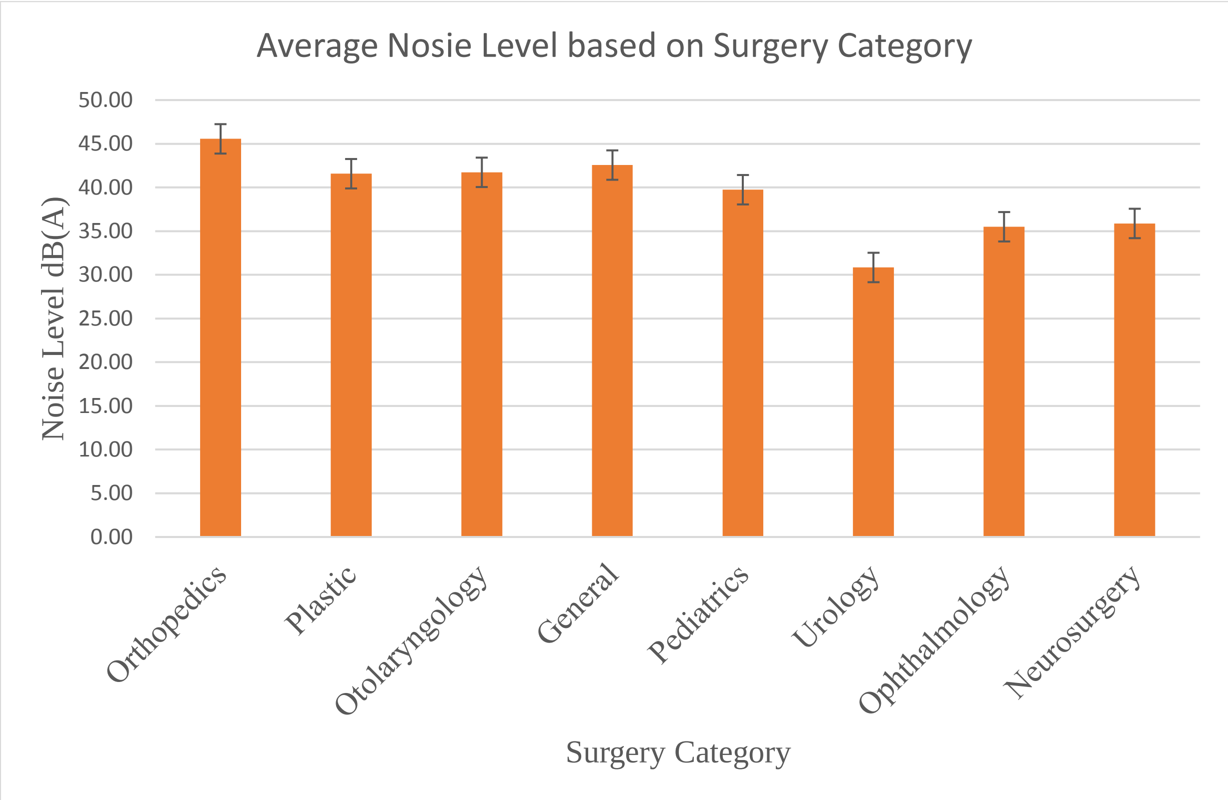

Figure 10. Average noise level based on surgery category

In terms of the difficulty of the surgery, average noise levels increased from surgeries that were rated as 1 (very easy;36.77), to surgeries rated as 2 (39.87), and then decreased to surgeries rated as 3 (38.92), to surgeries rated as 4 (35.07), and then increased to surgeries rated as 5 (very difficult; 38.82) in that order, but the difference between these surgery difficulty groups was not statistically significant, F (4, 33) = 0.496, p = .739, η^2 = 0.238. The group means were not significantly different ($p > .05$). Figure 11 shows the average noise level based on surgery difficulty.

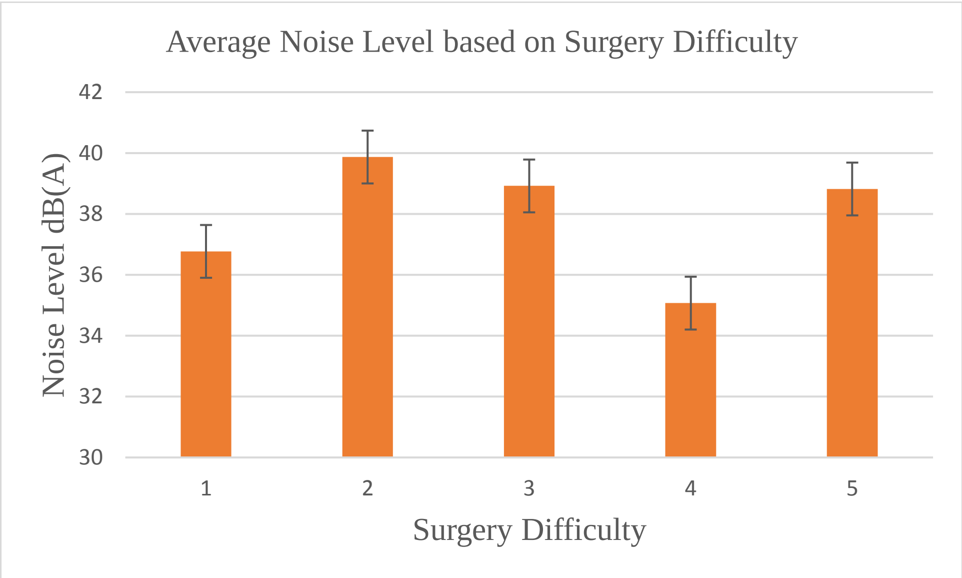

Figure 11. Average noise level based on surgery difficulty

Average noise level decreased from the morning surgeries (38.83), to the afternoon surgeries (37.61), and then increased to the evening surgery (39.96) and to the night surgery (48.42) in that order, but the difference between these surgery time groups was not significantly different, F (3, 34) = 1.189, p = .329, η^2 = 0.308. The group means were not significantly different ($p > .05$). Figure 12 shows the average noise level based on surgery time.

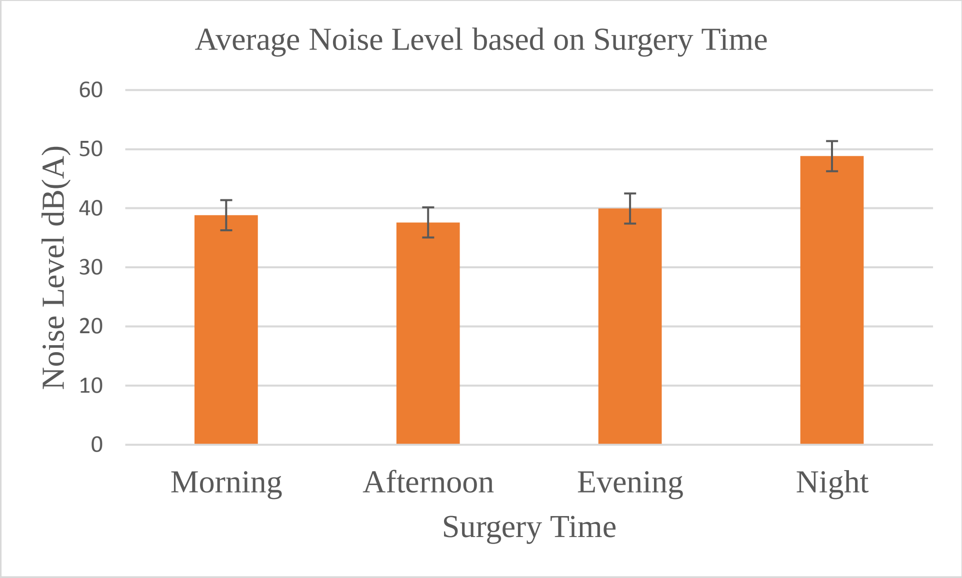

Figure 12. Average noise level based on surgery time

2. Effect of Music

A Kruskal-Wallis H test was conducted to determine if there are any differences in the effects of music on performance, communication, and concentration between surgeries of different music types. Surgeries were classified into three groups: Arabic (n = 5), Non-Arabic (n = 7), and Instrumental (n = 9). Values are mean unless otherwise stated. Effect of music on performance, communication, and concentration scores were not similar for all music types, as assessed by visual inspection of a boxplot. Effect of music on performance decreased from the Instrumental (4.11), to Arabic (3.4), and then increased to Non-Arabic (4.00), in that order, but the difference between these musical groups was not statistically significant, $\chi 2(2) = 2.861$, $p = .239$. Effect of music on communication decreased from the Instrumental (3.67), to Arabic (3.4), and then increased to Non-Arabic (3.71), in that order, but the difference between these musical groups was not statistically significant, $\chi 2(2) = .632$, $p = .729$. Effect of music on concentration decreased from the Instrumental (4.00), to Arabic (3.40), and then increased to Non-Arabic (3.71), in that order, but the difference between these musical groups was not statistically significant, $\chi2$ (2) = 1.656, *p* = .437. Figure 13 shows the effect of music on performance, communication, and concentration based on music type.

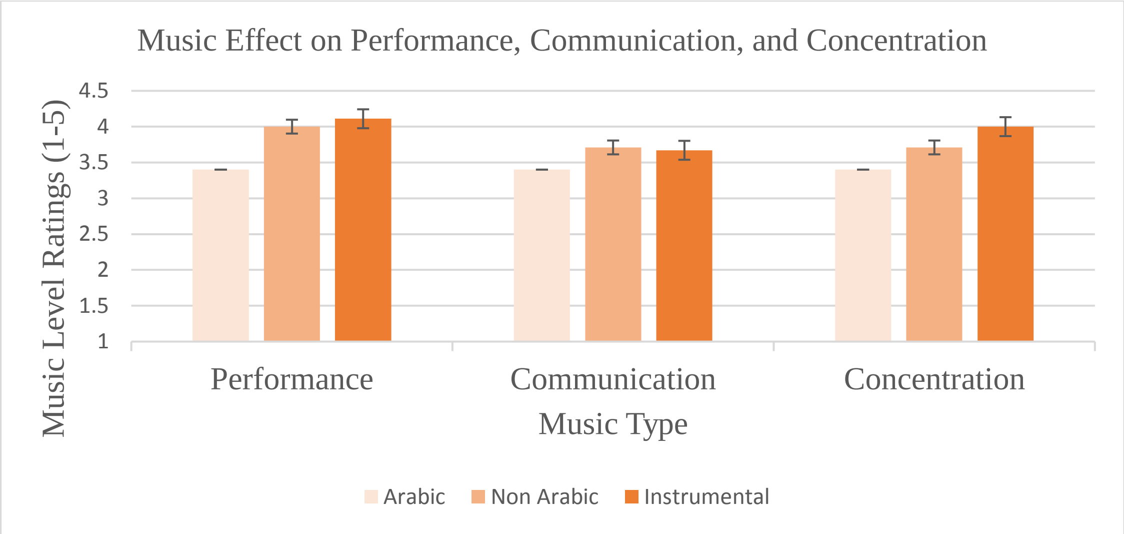

Figure 13. Music effect on performance, communication, and concentration based on music type

E. Analysis for Objectives III and IV

Analysis of the qualitative interview data was made to extract further information with regards to the effects of music and noise. This would then link to both Objectives III and IV.

More than 70% of participants found music to be beneficial during surgery and 50% believed that it is better for music to be used in the middle of the surgery, during routine tasks, and not all the time. Also, when the music does not meet their preference, 80% of the participants saw music as a distracting factor that adds to the noise. In addition, according to the interviews, 55% of participants mentioned that music is typically used during long cases of orthopedic surgery, general surgery, and plastic surgery. Also, 23% of the participants mentioned that during complex, critical, emergency, and high-risk cases, music is often avoided. Also, one participant pointed out that music is avoided during robotic surgeries in order not to interfere with the Bluetooth devices and the medical robot being used. In general, however, only 17% mentioned that they find either music or noise disturbing. Around 21% said that they just get used to the noise.

With regards to the sources of the noise, results showed that instruments used during surgery led to almost 17% of the noise, conversations led to 53% of the noise, and technology (e.g., telephones, the ventilation system) led to 20% of the noise. Finally, with regards to the type of music that is mostly played during surgeries, 47% of participants mentioned that pop and rock music is mostly played during surgeries and 55% of participants mentioned that classical music is usually played based on their overall impression of OR music.

CHAPTER V

ANALYSIS AND DISCUSSIONS

The overall goal of this research was to analyze the perceived effects of noise and music on performance and attention of medical personnel in the operating room. This was done by collecting noise measurements and conducting concurrent surveys in order to determine to what extent noise and music are a problem and what factors play a role.

A. Noise Level Measurements and Environmental Factors

Overall, the monitored surgeries spanned a range of Leq from 36.8 to 45.0 dB(A), and the averages ranged from 28.8 to 52.2 dB(A), with an overall average of around 40 dB(A). This is a tighter distribution of levels than the previous measurements that were recorded at AUBMC using a sound level meter of type Lutron SL-4023SD. There could be two possible explanations for this. The first is that the current iPad measurements might be not reliable or properly set up, in which case, the OR administration needs to further assess and evaluate these sensors to make sure they are providing accurate data. The other possible explanation is that the noise-reduction initiative implemented by AUBMC, led by Dr. George Zaytoun, has resulted in a considerable decrease in the amount of noise in surgeries. The average noise across all ORs measured using the earlier sensors was around 60 dB(A) as compared to the current value of around 40 dB(A). Given the very large difference between the two values, however, it would seem unlikely that the new program alone has led to such a change. In general, though, both values are above the World Health Organization (WHO) guidelines of 35 decibels (dB(A)) equivalent continuous sound level L_{eq} during the day and 30 dB(A) L_{eq}at night in patients' rooms. This suggests that despite any potential improvements, the noise levels in ORs at AUBMC are still relatively high. The concerns raised by high sound pressure levels in ORs include the potential for hearing loss on the long term. The sustained sound pressure levels found in the OR are not sufficiently high to cause significant hearing loss.

Furthermore, the difference in the mean noise levels between surgical types is statically significant, with orthopedics and open-heart surgery being the noisiest specialties. Orthopedics, in particular, is known to use many noisy tools (e.g. Holze et al, 2014), so the fact that it emerged as the noisiest specialty validates the noise sensing system. At the same time, it is interesting that interviewees seemed to think that conversations, not tools, are what contribute the most to the noise, suggesting that for them, tool noise might be easy to tune out, whereas conversations might be more bothersome. This contradicts other studies (e.g. Ginsberg et al., 2013, Chen et al, 2012; Holze et al, 2014), which have shown that the source of noise in the ORs are linked mainly to surgical instruments used during surgeries There was nothing in the results to suggest that difficulty contributed in any way to noise levels.

In addition, the effect of noise on concentration was found to be significantly different between different surgery types.

B. Medical Personnel Characteristics

A main contribution of this thesis is to explore the medical personnel characteristics that contribute to the effects of noise and music. Only a few studies have examined the effect of noise on the performance and concentration of the medical personnel during surgical procedures. Moorthy et. al (2004) showed that neither noise or music have any effect on task performance. This finding was replicated here; results showed that medical staff can effectively block out noise. This was also confirmed by the fact that many said they simply get used to the noise. This is in line with results from earlier studies (e.g., Moorthy et. al, 2004; Keller et. al, 2016), which found that noise has no effect on the performance or concentration of medical staff in the OR. It would appear that noise has no effect on the technical skills of the medical personnel, which is reassuring for the safety and wellbeing of surgical patients. However, it does seem that medical personnel admit that noise interferes with their communication. This also confirms earlier findings; for example, Rogério et al. (2012) showed that noise in the OR significantly degraded communication among medical team by interviewing medical personnel working in the OR. In addition, our analysis showed that there no differences in communication ratings across roles or specialties, suggesting that surgeons, residents, and nurses are all in agreement that noise can affect concentration. However, there was a difference when it comes to age, with regression model coefficients suggesting that younger medical personnel (below 40) are more affected by the presence of noise.

Another key finding is that music can help overcome the effects of noise. It seems that music has a positive effect on the staff working in the OR and is not considered as "noise" by them. These results confirm the findings that were obtained by Yehuda et al. (2006), who showed that music makes medical staff working in the OR calmer and more efficient Similarly, Yamasaki et al. (2014) also found that music improves concentration, alleviates stress, and enhances performance. However, they found differences between nurses and physicians. In this study, there was no difference found between medical roles. In general, for all these specialties and roles the mean value of music effect exceeds 4, which is suggests that medical personnel tend to enjoy music in the OR.

Finally, the difference between music types did not have a significant effect on medical staff. This is because the selection of music is not related to the procedure type; rather, it is based on the surgeon's preference. All these models show that the mean value for each of the reported value on the effects of music on performance, communication, and concentration has a value above 4 on a scale of 5. This further suggests that music improves concentration and team communication instead of being a distracting factor. Once again, this contradicts the results of previous studies; for example, Weldon et al. (2015) showed that playing music in the operating theatre during surgery is associated with significantly more repeated requests where surgeons have to repeat the request of a task from a nurse more than once because the nurse doesn't hear from the first time.

C. Research Limitations

It's significant to specify the incurred limitations in our whole research to open wider opportunities for future researches. First, for the measurements, the iPads were newly installed in the OR and we think maybe they weren't giving us accurate data especially that no one compared the data from the iPad with data measured using sound level meter that is generally used in such a research. Second, in the data collection process we encountered some problems with assigning interviews medical doctors because they were very busy with surgeries and the response rate was very low for them.

CHAPTER VI

CONCLUSION

This study aimed to determine the effects of noise and music in AUBMC ORs on the performance and attention of medical personnel as well as on the communication between these team members. The results were meant to provide more fine-gained knowledge of the benefits and/or dangers of music and noise with regards to several environmental and medical personnel characteristics. In conclusion, the results indicate that there is still more work to do to decrease noise levels, particularly in noisy surgeries such as orthopedics. At the same time, AUBMC medical staff can effectively block out noise and not allow it to affect performance or concentration; however, it does seem to affect their communication, which is also an aspect that needs to be worked on. Moreover, music has positive effect on the staff working in the OR and is not considered as noise by them since it improves concentration and team communication and it makes them calmer and more efficient.

A. Intellectual Merit

While the effects of noise and music in the ORs have been examined in different studies, the combined effects of both music and noise in ORs has been limited. Until today, none of the studies performed in this field focused on analyzing the combined effects of music and noise. Studies examining these effects also were limited in terms of their focus on the complexity and the diversity of the environment. As a result, this study helped establish a more comprehensive understanding of the association between noise or music effects based on both surgery specific data and medical personnel characteristics.

B. Broad Impact

This study will contribute to the improved health, safety, and wellness of medical personnel involved in ORs. This, in turn, will translate to improved OR efficiency and, ultimately, better patient care and wellbeing.

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