Design and preliminary testing of the test apparatus to analyse the impact of hearing problems on the ability to repeat sound by singer

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Abstract: It is likely that serious hearing loss affect drastically human possibility of repeating the sounds. Remains the question of whether and how the delicate hearing loss affect the person’s ability to repeat sounds. Therefore we try to create the database samples singing, expanded on the tests of hearing for individual singers, that could be used to further research in this direction. The studies were used two research stations one for the hearing test, and a second used to test the ability of the singer to repeat sound. First station used for hearing tests utilized a standard, certified audiometric cabin with cooperating with her professional audiometer. The second test station was design for record and analyse singers ability to repeat sound. Projected solution, use tools for both generate, playback and recording audio, with used additional materials to improve the acoustic performance of the tests. This article describes the design of test aparature and presents the conclusions of the preeliminary tests, in particular those related to the second set of equipment.

Keywords: hearing loss, intonation, singing, voice

1. Introduction

Musicians and artists are occupations with the highest potential to hearing loss caused by noise [1]. They become people with hearing impairments, because too loud music can damage hearing. It interferes with the action of the natural mechanism to protect the hearing against acoustic shock. This mechanism is called the acoustic reflex. The middle ear is working as mechanical transmission matching the sounds of air to the liquid environment of the inner ear. This gear, consisting of the ossicular chain, acts as a mechanical lever, but the brain can adjust the power of the feed back of transmitting acoustic wave[2, 3].

It is well known that severe hearing losses prevent or substantially hinder the repetition of sounds. There have also been cases of musicians (composers or singers) who, despite the loss of hearing continued further their artistic activity. A famous example is the case of Ludwig van Beethoven. Around the age of 30, Ludwig van Beethoven started becoming deaf [4, 5, 6]. Although the composer tried to counteract his deafness, using different kinds of hearing aids created especially for him, but when confronted with the disease they have been ineffective. It should be pointed out that Beethoven, in fact, was not deaf - it is wrong to think that he heard nothing. He had heard, but in a very special way. This shows the complexity of the issues investigated in this article. Hearing loss is not only impair your ability to hear sounds with increasing intensity. Hearing loss is also changing the configuration of received sounds.
Beethoven had just such a problem. However his struggling with it was his genius. The imperfections of hearing was compensated by brain.

While in the case of Beethoven’s solution was to transfer the memory of the sound phenomena occurring outside the listener to the inside of his mind, it is somewhat different in the case of singers. Vocalists during singing trying to control the voice emission based on the feedback. Produced in a complex process of voice emission sound is subjected to analysis via the of hearing in the brain. Vocalist hearing their possible shortcomings is able to improve the quality of sound.

An 2016 example of the vocalist losing hearing is 68 year old Brian Johnson, the leader of the band AC/DC. The team moved their concerts in the US due to the health condition of their leader [7]. Doctors say that if he did not discontinue touring now, then he may completely lose the ability to hear. However, even with the significant detriment of hearing vocalist performed until recently exhausting concerts. Vocalist (his brain) was therefore able to compensate for the damage of his hearing.

The process of singing is actually very complicated and hearing loss does not have to affect the quality singing. Everything depends on several factors:

— vocal experience of the singer,
— "memory" of the vocal apparatus,
— the degree and type of hearing loss.

So the questions remain:

— What is a small dysfunction of hearing?
— Whether and how small hearing dysfunction affects this ability?

Motivated by these questions, we decided to investigate the possible links. Research requires the use of two sets of test apparatus: one serving hearing test and a second serving registration samples of singing, which will later be used to analyse the ability of the singer to repeat the sounds. In this article, we focus precisely on the test apparatus and preliminary tests before using them in research.

For the purposes of research in the role of artists exposed to hearing loss were played by members of The John Szyrocki Memorial Choir of the West Pomeranian University of Technology in Szczecin [1]. The singers differ in their advancement level and the number of the years spent in the choir. All the singers were healthy. All of them are active members of the choir. The investigation focuses mainly on their abilities to hear and repeat sounds at particular frequencies. It might be possible to observe the relationship between the results of hearing tests and their abilities to repeat songs.

2. Test equipment

The first research station consists of a certified audiometric chamber, along with audiometers. The station aims to carry out different tests of hearing. The aim of the study is to detect which frequencies singer hears less. Our assumptions indicate that the repetition of these frequencies, the singer may have the greatest difficulty. However, it is possible situation that precisely those frequencies can be less problematic because the singer can automatically try to compensate for the hearing loss in an automatic way.

The second research station can be described as a station for record singing along with the reference tone. The idea to build a research station for this purpose, which will allow us to record in the right way, comes from our repeated experience in carrying out this type of
recordings and the desire to eliminate the problems that we encountered. The most disturbing in the analysis of the recordings were:
— Singers usually start to sing during the decay of the reference sound,
— Disturbances during registration,
— Distraction singer - occur from both fatigue of singer and external factors.
There are many ways to eliminate them, but our main limitation was the possibility to use already possessed by us space and hardware resources. Itself research station is only half of the research process. The second part is the software used to study singing voice, which was created as a result of our research [8, 9, 10, 11].

2.1. Tests of hearing

Used by us audiometric chamber was made by EYMASA. It provides partial isolation of test subject from external factors. However, due to its small size and the impossibility of installing the active ventilation system, the process itself is often limited in time due to the comfort of the subject.

Audiometer SIBELSOUND 400 from Sibelmed, is equipped with air headphones and the generator for bone conduction. The chamber is equipped with soundproof doors and a window enabling eye contact between the subject and the researcher. Additional contact is available via intercom allowed by small microphones. The study consist of playing (or not) sound for a particular channel of headphones and receive feedback if audio signal is heard by the subject. Subject emitted it by pressing a button. The study of hearing conducted by us was to determine the equal-loudness contour threshold and compare it with bone conduction.

2.2. Tests of ability to repeat sound

Construction of research station was planned taking into account the aforementioned limitations resulting from limited access to equipment and facilities. The first idea was to use professional studio headphones (PreSonus HD7) for both the singer and researcher. These headphones suppress sufficiently the surroundings in order to minor interference from outside did not distracted singer. Another advantage was the ability to play audio reference directly on the headphones, without releasing it in the room, so it was not recorded by the microphone.

To the recordings was used AudioTechnica AT-4050 microphone set to cardioid characteristic. In this particular model it is so good that it works almost like a directional microphone and not collects sounds and reflections from other directions than the front. To get rid of extra reflections from the direction registration singer was surrounded by mats from the conical noise-shield foam.

To record audio samples was used recorder Zoom H4n, which can be treated as a quieter substitute for a computer. This helped to eliminate extra noise that would generate other device equipped with a fan. Recording was carried out in two channels: the first contains only sound as a reference signal. As the sound source was used ToneBank Casio CT-670 synthesizer. It was set to the sound closest to the piano, and before each recording session was tuned to the correct frequency. To the second channel was adjusted sound recorded by a microphone, which was analysed. The whole was connected by a the multichannel interface Motu 893mk3, which in this case was used as a mixer, and was supposed to allow adjustment of volume levels and the ability to provide feedback for singer. Diagram of connections between devices is presented in Figure 1.
3. Apparatus tests

The tests carried out were aimed not provide us with a ready base of samples, but check if received by developed research station data can be used to create such a database. Additionally we gather all the information about the disadvantages encountered that prevented comfortable carrying out the study. The correct conditions for obtaining samples for the database is a key condition for an objective analysis.

3.1. Tests of hearing

During the tests, of hearing examined several people to check the apparatus and the convergence of the results for different users. Also collected opinions on the study and the conditions of his conduct. Studied the equal-loudness contour threshold and a small fragment of Webber test.

During the tests, we encountered several problems. The most serious is taken from the location of the room in which the audiometric chamber is, and building construction. Unfortunately, the frame of the cabin transfer various types of vibrations and noises echoing in the room or directly near him. Another problem is the duration of test. Despite the favourable temperature, the length of the study should not approaching the 10 minutes. Around this time in the chamber becomes too hot and uncomfortable, which reduces the concentration of the object.

An additional difficulty is the visual suggestion, due to eye contact between the object and the researcher. This leads to the situation that the test presses the button, although there is no signal. Because it seems to him that he heard because it is assumed that the operator has pressed the button. This introduces some procedurally difficulties hindering the unequivocal
evaluation of results. The operator must carry out the study in such a way as to be able to register when these situations occur.

Additionally after the analysis of preliminary studies it was observed that they contain relatively little information. Data collected in the database should be extended for a few more tests in the field of diagnosis of hearing. It would be useful also utilize carrying out the automatic analysis, in order to accelerate the testing, which allowed to carry them more similar time.

3.2. Tests of ability to repeat sound

Tests of registration can be considered as successful. They refined some basic assumptions and settings. The first assumption concerns the singer. He should be between the microphone and foam damping. His mouth should be located at a distance of about 30 cm from the microphone. Before the beginning of recordings should be also check the maximum volume of the singer, because while singing the higher notes singers tend to increase it. This procedure helps to avoid subsequent clips that are problematic due to the inability to use sounds limiters.

Both the singer and researcher have headphones on, in which they hear both the piano and singer. A critical aspect is the selection of appropriate volume in the singer’s headphones in which his voice will not be amplified, but had a similar volume to the natural one which reaches him from the environment. This requires very precise calibration in order to headphones gave the impression that they do not exist.

The last aspect of this study was to analyze of samples. The samples were stored in the WAVE format 24 bit 48kHz. They were dual channel. Left channel contains only the reference sounds and the right channel sound recorded by the microphone. This division significantly facilitates the analysis of intonation by comparing the pitch in both channels.

4. Conclusions

During the test we obtained a number of conclusions, some of them applies to both research station. As for the hearing test we have to limit their length. A longer examination time has a negative impact on their effect. This affects both the time to focus on the task and the lack of adequate ventilation in the cabin. The conclusion of the research itself is the need to expand testing of additional elements of diagnostic of hearing as well as automated testing, which can speed up research. Despite the soundproofing of the cabin, structurally it transfers the vibrations at certain frequencies, therefore tests can be carried out only in the moments when in the hallways are empty.

Similar limitations encountered when conducting recording. Despite the partial silencing of the room and extinguish part of the stimuli via headphones, they failed to eliminate them all, because it was found that the registration should be carried out in the reduced activity of teaching. Additionally we must clearly highlight the importance of a properly set the volume on the headphones. You have every partner is informed about and take care of it order to meet the assumptions of the experiment. An important aspect of the station is a two-channel recording of samples which allows much easier analysis and segmentation of samples. Finally, it should be noted that the same station greatly enhances our ability to registration of samples and conducted experiments allowed positively assessed its usefulness.
References