PERSPECTIVES OF PERFECTING THE AURAL SKILLS OF SOUND ENGINEERS

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Abstract: Aural analysis training on various levels (dynamics, frequency, time) should be one of the basic training activities of all those who want to work with sound, not only of professionals but also of amateurs and students attending the Music and the Computer course at the primary level of art education. On the other hand, these are among the most undervalued skills, with inadequate accent on the necessity of their active and systematic training.

Keywords: sound, music, training

1 Introduction

Research on the contents of the education materials and curricula of the Music and the Computer course, published in the scientific monograph Technology and Technical Devices in Music Education: Starting Points, Situation, Perspectives[1], reveals that only minimal attention is paid to aural analysis. Despite the fact that, for practising sound engineers, their skills to analyse sounds are crucial. These skills can be fully developed only by active listening, whether to high-quality music recordings or to specific sounds, such as white noise or pink noise. It is important to note that the purpose of the development of aural skills is not to influence the level of artistic perception or to shape one's taste in music and sound. Its purpose is primarily to develop the technical sphere of aural skills, which are an indispensable tool to shape the taste and preferences of a sound engineer.

In practice, a sound engineer's auditory system and the technological background (the recording studio) he's working with become his musical instrument. Currently, technological advancement enables even students to acquire tools for editing sound and the age limit of using such tools keeps decreasing. Besides the technological equipment, therefore, it is increasingly important to develop abilities and skills, especially aural ones, too. The quality of developing aural skills, however, is directly connected to the technical conditions and requirements of playing audio recordings. In "local" conditions, the main problem in having an ideal listening environment is the absence of a suitable acoustic arrangement of the rooms and the lack of reproduction technology in the form of studio monitors.

Consequently, most students must use a more efficient and less costly solution – headphones. Although headphones play a role and have their place in professional studio work, for adolescents, they become the only option to listen to sound recordings in better quality than through cheap computer speakers. The phenomenon of the frequent and improper use of headphones by the young generation has been studied for over two decades. Several scientific studies[2] reveal alarming results because the vast majority of the respondents listens to music through headphones for an unreasonably long time at high volumes. Measurements in laboratories revealed that safe use of headphones, that does not damage the auditory system, should meet the requirement of maximum 80 dB of volume for a period of 8 hours.

Increasing the volume radically decreases the period for which the headphones can be used. If the ears are exposed to extreme load, they can get severely damaged. The most frequent damage, increasingly affecting young people, is tinnitus. It manifests itself in constant intense perception of a particular frequency independently from the sound environment one is exposed to. This hearing impairment significantly reduces the quality of one's life and it is irreversible. Therefore, aural hygiene is one of the top priorities in the education of the younger generation.

Each training, aural, too, requires a systematic approach and compliance with certain mental hygiene standards. It must be kept in mind that the time dedicated to aural training must be limited. On the one hand, because of the acoustic pressure that the hearing is exposed to, and, on the other hand, because of the mental load during intensive focus on aural perception. The human auditory system gets tired relatively fast and the feeling of tiredness, often accompanied by frustration if the answer is incorrect, appears after only a few minutes of intense training. From this moment onwards, any training becomes an end in itself and highly counterproductive. Therefore, training must be divided into several training cycles that include adequate time for letting the auditory system rest when the person is not exposed to any aural load.

However, the training time to be followed cannot be clearly specified since it depends on several determinants. One of the most important ones is the nature of the sound source used for the training. In aural exercises focusing on the sound engineering field, two basic sound sources are used – pink noise and music. Pink noise, as a simple sound to perceive, is used primarily in training the analysis of the frequency spectrum, and a more complex form of sound, music, is analyzed only later. All the other training methods use predominantly musical sound.

When using pink noise, the auditory system is loaded several times more than in the case of music. The reason is that pink noise contains, simultaneously and in every time section, a uniform dynamic distribution of all the audible frequencies of the frequency spectrum. The advantage of this type of sound is that changes in the volume of the given frequency are clearly audible during the training. When using pink noise, the aural training time is only a few minutes per training cycle, which must be followed by a break. Training using musical sound can be carried out in more cycles because auditory perception is not loaded to a high extent.

The requirement for training aural skills to achieve efficient and high-quality work with sound has been present probably from the very beginning of the sound engineering profession. Initially, trainings took place mainly indirectly, during the work itself with sound. Sound engineers acquired the required aural experience only through long-term practice. There were no didactic procedures or exercises. The situation changed radically only with the emergence of digital technologies, which became available to the general public, too, not only to professionals.

A general availability of digital technologies started in the 1990s and it made the first ever complex education programme focusing exclusively on the development of aural skills possible. This education programme was Dave Moulton's book, Golden Ears[3], from 1995. This didactically oriented publication was accompanied with 8 CDs containing exercises for the frequency spectrum, dynamic range, reverberation and delay. A shortcoming of these types of exercises is that all the changes in the samples are fixed, built into the audio recording, and the user cannot adjust the educational contents. Another problem is the presence of the unchanged musical samples, which become boring after some time.

More complex and user-friendlier interfaces could be achieved only by software solutions, which, however, could not be developed at that time due to a lack of technological tools. A significant change took place only with the development of the Internet and of websites, when several sites came into being that offered basic user interfaces for perfecting aural skills. Specialized sound engineering educational software began to be produced only a few years ago and its emergence was partly

[1] BREZINA, Pavol. Technika a technológie v hudobnom vzdelávaní - východiská, stav, perspektívy.
[2] FARINA, Adriano. A study of hearing damage caused by personal MP3 players
[3] MOULTON, David. *The Golden Ears*.

inspired by the development of mobile devices such as smartphones and tablets. Currently, an enormous number of both Apple- and Android-based applications exist for these devices. However, the applications were developed mostly for entertainment purposes and do not have a more profound didactic purpose.

Specific, didactically oriented pieces of software for sound engineers began to appear only after 2010. Products by Harmann[4] or TrainYourEars[5] are designed in a sophisticated way and offer the users comfort in setting the exercises or choosing the sound source (noise, music etc.). V-Plugs was also among the first developers, and it later transformed its Mr. Soundman product into the extremely successful web interface Soundgym[6], which became popular all over the world.

Today, there are several similar web applications and audio CDs that support this type of training. Not all are acceptable from a didactic aspect, though, and some are outdated. Corey[7] defines the following five basic categories to be implemented into ear training:

- Frequency spectrum analysis – equalization
- Attributes of spatial perception – delay and reverberation,
- Attributes of the dynamic range – compression/limiting and expansion,
- Elements of the quality of an audio recording – distortion and noise,
- Processing audio materials – cutting and editing audio recordings.

A very important area, the ability to distinguish the timbres of musical instruments, is missing from the above division.

1.1 Frequency Spectrum

Theoretically, an undamaged human auditory system can perceive frequencies ranging from 20 Hz to 20,000 Hz. With age, the perceivable frequency spectrum, especially the high frequencies, gradually decrease. Frequency spectrum training, therefore, must take place in conditions that minimize the negative impact on the auditory system. The 20 Hz to 20,000 Hz frequency spectrum contains a very wide range of frequencies whose wavelengths move from 19.8 metres in the deepest frequencies to some 1.25 centimetres in the highest ones.[8] Therefore, a set of loudspeakers in an acoustically well-adjusted room should be ideally used. The requirement to adjust the room acoustically is essential for the right identification of the audio frequencies during training. Ideally, the right acoustic solution would provide a frequentially balanced course of the reproduced sound but, due to physical limitations, we can only come more or less close to this ideal in practice. Despite the fact that acoustic adjustments are aimed at creating a balanced, linear, course, we should bear in mind that the human auditory system does not perceive sound in a linear way.

The shape of the frequency curve of the human auditory system was identified by Fletcher and Munson based on their research already in 1933.[9] The equal-loudness contour – as the two researchers named it – demonstrates the fact that the human auditory system is a lot more sensitive to the frequency band of medium and higher frequencies (1000 – 4000 Hz) than to frequencies in the bass band. Being aware of this fact can help trainees who undergo ear training in the frequency spectrum.
Standard training to distinguish frequencies is carried out by increasing or decreasing the volume of the given frequency, which the percipient must be able to identify correctly. The aim of the training is to acquire the ability to immediately identify the presence of prominent or dampened frequencies in an audio recording that should be treated in terms of volume. In general, it is simpler to train the identification of frequencies when increasing the volume. Therefore, it is recommended to approach the training focusing on the identification by turning down the volume only later on. Also, several types of curves (bell, shelf or pass) are usually used for frequency spectrum training. To comply with the didactic principle of graduality from simple to complex, it is good to start with the bell curve and include only a narrow frequency spectrum.

1.2 Didactic Tools for Frequency Spectrum Training

For many years, the only possible didactic tool consisted of sound recordings, which had a preset type of filter and a specific level of increasing or decreasing the volume for the given frequency. The number of questions was thus finite and, from the aspect of long-term training, quite dull. Software solutions, on the other hand, provide higher flexibility in setting the exercises and the principle of motivation becomes more lasting.
In this area, the most sophisticated training program is TrainYourEars. It enables the users to set the exercises from basic and simple ones (e.g. identification of a single frequency) up to extremely difficult ones, incorporating several frequencies into one question (one question may include all types of filters – bell, shelf and pass). By default, the program contains two types of sound for training – pink and white noise. However, users may choose any audio file in the wav, flac or mp3 format for training. The program is suitable for beginners, e.g. students of the Music and the Computer course, as well as for professionals or students of higher education programmes focusing on sound design. The whole user interface is now translated into Slovak, too.[10]

Besides standard computer programs, there are a number of web applications compatible even with mobile devices. This trend has been very popular in recent years and enables users to train their aural skills anywhere. The most sophisticated web application is SoundGym, which provides several types of training focusing on the frequency spectrum. These trainings, however, cannot be edited and function only at the difficulty levels preset by their developers. The whole concept of the application has the character of a computer game with a high-quality user interface in terms of graphics and with gradual levels up to difficult categories that are highly motivating especially for younger users. However, from the aspect of systematic and specifically didactically oriented education, the application cannot be used very well because the exercises cannot be edited.

1.3 Spatial Perception

Spatial attributes are defined by several elements. The most important ones include two types – delay and reverb of the audio signal. Both these elements are part of ear training and should be practised separately first. Even though both cases represent delaying the audio signal, they are defined in a different way. An audio signal that is delayed up to 50 milliseconds is called reverb and the human auditory system perceives the various elements in this time span as a uniform audio element. Behind the 50-millisecond limit, however, the auditory system distinguishes two or more independent audio elements.[11] Being aware of both types of delaying the audio signal and differentiating between them plays a very important role in making the right decision when editing sound. The basic types of reverb are chamber, hall and plate. Each has a different structure of the temporal distribution of the delay and the reverb elements, while the plate type, for example, does not contain the initial reflection (delay) element at all.

[4] How to Listen! *Harmann's How To Listen!* [online]. [cit. 2019-11-26]. Available at: http://harmanhowtolisten.blogspot.com/2011/01/welcome-to-how-to-listen.html
[5] Train your ears. *Train Your Ears* [online]. [cit. 2019-11-26]. Avaliable at: https://www.trainyourears.com/
[6] SoundGym. *SoundGym* [online]. [cit. 2019-11-26]. Avaliable at: https://www.soundgym.co/dashboard/index
[7] COREY, Jason. *Audio production and critical listening: technical ear training*. p. 8
[8] STREICHER, Ron a F. Alton EVEREST. *The new stereo soundbook*. p. 2.4
[9] HARVEY, Fletcher a Munson W. A. Loudness, Its Definition, Measurement and Calculation. p. 394
[10] The translation of the program took place after an agreement with its developer as part of the KEGA 023UKF-4/2018 Extended Possibilities of the Application of Information and Communications Technologies in Music Education project.
[11] MOULTON, David. *The Golden Ears*. p. 58

Besides spatial perception, delaying audio signals can be used based on the various types of reverbs also for training the localization of the audio signal on a stereophonic base, a so-called stereo panorama. Thanks to the delay of the sound waves, the human auditory system can identify the location of the sound source in space and is extremely sensitive to these delays. If the listener sits in front of a stereophonic reproduction system at a central point, he or she will perceive even a 0.2 millisecond delay of the signal in the left or in the right speaker as a slight deviation from the central stereo base. The listener will perceive a 2-millisecond delay as a complete shift of the sound source in the stereo base towards the left or the right speaker.[12]

Spatial perception training is complex and difficult. Consequently, it is recommended only to advanced students. By using the right didactic reduction, however, this type of training and, especially, the localization training in the stereo panorama, could be handled even by students attending the Music and the Computer course.

1.4 Didactic Tools for Spatial Perception Training

In the past, similarly to frequency spectrum training, spatial perception training figured only in the Golden Ears book. Exercises focusing on delay and reverb had limited scope within the training, since they contained fixed time values. Dave Moulton stated that the most important time band for training delay is the interval from 30 to 70 ms.[13] Currently, however, even values exceeding 500 ms play an important role in sound engineering, mainly due to the aesthetic requirements for sound in modern musical productions. Training reverb, therefore, should be oriented primarily towards defining the band of initial reflections and the time of the reverb, given in seconds. Currently, there is no sophisticated software application that would take into account the above specifications. The only application that offers a simplified training of delay and reverb is SoundGym.

At present, the only viable solution is to create one's own exercises by music software that contains delay and reverb effects. Based on the required level of difficulty, the exercises can be created in a complex or in a simple way. A simple basic exercise can consist of comparing two significantly different time values (e.g. 50 ms and 500 ms), with the user having to determine which one is longer, and which one is shorter. This interval can be gradually narrowed down, by which the difficulty to identify the difference increases. A complex exercise may set the task, for example, to determine the value of predelay, which is often used in reverb devices. The task of such delay is to separate the reverb from the original audio signal (e.g. to increase the clarity of singing or speech).

Reverb training can be carried out by any reverb plugin in which halls of various types and sizes can be set. In this aspect, the convolution reverb produced by Altiverb is an ideal solution, as it contains models of dozens of famous concert halls and other interesting halls in terms of sound. Being aware mainly of the duration of the reverb, in seconds, plays an important role in reverb training.

1.5 Dynamic Range

The dynamic range of an audio recording is specified in decibels of the sound pressure level (dB SPL). For the human ear, the range is limited by the auditory threshold at 0 dB SPL and by the threshold of pain at 120 dB.[14] A standard conversation between people takes place at 60 dB SPL and the volume level when listening in a recording studio should be somewhere around 75 to 85 dB SPL.[15] In the field of dynamic range, ear training focuses primarily on the acquisition of the ability to discern even minimal changes in the volume level of the audio material. This ability is of key importance in making the right decisions when mixing music where the right volume level is to be determined for the various sound sources (musical instruments) to achieve a dynamically balanced audio image.

However, a trained auditory system is able to discern even dynamic changes of 1 dB SPL. Training must start with higher difference levels though. Usually, 3 dB (which represents a double intensity of the audio signal), 6 dB and 12 dB values are practised. Beginners start with the 12-dB level and decrease it gradually. Standard training to distinguish the volume takes place by comparing two audio signals, where the task is to determine which one is louder, and which one is softer.

Besides comparing the volume levels, specific skills to distinguish the settings of specialized instruments to adjust the dynamics, such as compressors, can also be trained in the field of dynamic range. The ability to identify the level of the ratio of the dynamic range compression of a sound recording, or to specify by ear the attack or the release of the compression, is also one of the key abilities of a qualified sound engineer. Highly specialized aural skills connected to dynamics include the identification of the distortion of the audio signal, which can also be trained with compressors or limiters.

1.6 Didactic Tools for Dynamic Range Training

So far, there is no specialized software that focuses on the complex and systematic training of perceiving volume levels or the behaviour of the various settings of compressors. In part, three exercises in the SoundGym application deal with training the perception of the dynamic range. Two of them focus on distinguishing volume levels and one on dynamic compression settings. Again, however, these are only games which cannot be modified, and didactically more complex exercises cannot be created.

Any digital audio workstation (DAW) which enables working in the multitrack mode can be used to practice changes in the volume of the audio signal. To compare and differentiate between two volume levels, it is enough to insert an identical audio material into two audio tracks and change the volume level to the required level. By playing both the tracks solo, the listener can compare and distinguish the differences in volume. In this method, automatic evaluation of the answers is absent, and they must be recorded manually.

The perception of the compression level of the sound can be practised in a similar way. Either we insert the required compressor in one audio track and the listener will determine the settings of the parameters of the compressor based on the heard sound or the compressor can be inserted into two tracks with the audio material and the listener will determine the differences in the settings. In this case of practising, it is again only a manual form of recording and evaluating the results.

The possibility to automatize all the parameters can help in creating tests with several audio samples – questions. In the audio tracks, several audio samples with various compressor settings or, in the case of practising the comparison of volume, with various settings of the volume level, can be arranged sequentially. Practising dynamic range and perceiving the complex changes in the parameters is meant primarily for advanced users. In the case of the Music and the Computer course at primary schools of arts, it is recommended to begin with simple comparisons of the volume of two audio samples and to progress to practising dynamic range compression subsequently.

1.6 Quality Elements and Cutting Audio Recordings

The availability of devices for creating and editing audio recordings has risen significantly over the past decade. Technological advancement and the affordability of the technologies enable even amateur musicians and music

[12] STREICHER, Ron a F. Alton EVEREST. *The new stereo soundbook*. p. 2.14 – 2.15
[13] MOULTON, David. *The Golden Ears*. p. 58
[14] MOULTON, David. *Total recording: the complete guide to audio production*. p. 25
[15] KATZ, Bob. Integrated Approach to Metering, Monitoring, and Leveling Practices, Part 1: Two-channel Metering. p. 802-803

enthusiasts in home conditions to work with sound. The development trend of digital technologies focusing on creating and editing audio recordings, however, comes with some pitfalls. Firstly, they include the inadequate education of the users, which leads to an increasingly large amount of audio recordings of low quality from the technical aspect. From the aural aspect, we assess the quality of an audio recording based on the presence of audio elements that have a disturbing effect on the listener and degrade the overall impression from listening.

Such elements include mainly the digital distortion of the sound that occurs due to the incorrect setting of the sensitivity of the preamplifier during the recording or due to the incorrect use of tools in the post-production phase. Also, it includes the presence of noise and other interferences in the audio recording and, recently, the increased presence of strong reverb or even echo, which arises when the sound is recorded under acoustically unsuitable conditions (room, bathroom, classroom etc.). To eliminate the above elements successfully, an educated sound engineer must be able to identify all of them by ear. Since elimination takes place only in the post-production phase, it is an invasive and destructive intervention into the audio material. The right identification of the problem is the starting point for the right selection of the tools that intervene into the overall audio material during editing to the least possible extent.

Ear training to identify the disturbing elements in an audio recording must take place in acoustically suitable conditions, since these are often discernible only to a minimum extent and may vanish at the usual noise level of the surrounding environment. Headphones are therefore an ideal tool for this type of training because they minimize the influence of the surrounding noise and enable the listener to focus completely on the given elements. Identifying the disturbing elements of an audio recording is an extremely difficult process that requires experienced sound engineers. Consequently, it is recommended to start with their training only after enough time has been dedicated to exercises focusing on the frequency spectrum and the dynamic range.

Editing and cutting an audio material is directly connected to the identification and correction of the technical shortcomings of the audio recording. Today, the technical tools for editing sound make it possible to create cuts and remove unwanted sounds with high precision and in a non-destructive way. One can always return to the original material and edit the cutting in another way. The art of the right cutting of the audio material is based on long years of sound engineering experience. Training technically correct cutting is a process in which the sound engineer uses all the aural categories – the frequency spectrum, the dynamic range and the spatial attributes – reverberation.
To achieve the right cutting, the sonic continuity of the audio material must be respected, especially in the case of music and speech. Cutting materials recorded, for example, in a recording studio or at a concert of a symphonic orchestra in a cathedral with long reverb, offer various possibilities. In addition, the technical shortcomings of the audio recording often occur along with a signal that has an informational value (music, speech). In this case, cutting becomes a creative activity when the sound engineer, based on his aural skills, manages to identify the possibilities to replace such passages with another material in a way that does not affect the homogeneity and continuity of the sound or of the musical or verbal message. In the category of training the assessment of the quality of the audio recording, therefore, practising must be approached in a complex way as this is the most difficult form of ear training.

1.7 Didactic Tools for Training the Assessment of the Technical Quality of the Audio Recording

As mentioned above, the quality of the acoustic characteristics of the space plays the most important role in this type of training. Ideally, training should take place in a recording studio. If unfavourable acoustic qualities affect the efficiency of the training, it is better to use headphones. This variant is an ideal solution even for education at primary schools of arts where several students are present at the lessons of the Music and the Computer course and, therefore, loudspeakers cannot be used.
There is no specialized tool yet for training the identification of an undesired distortion of the signal. Consequently, we must make use of the available technical solutions, such as audio plugins meant specifically for the simulation of distorted sound. Although these are primarily meant to create significant distortion and are used in the post-production phase for guitar sounds, they can be set even to minimal distortion. An audio plugin set in this way can be inserted into the audio track with the respective audio material and, by manual assessment, the listener determines whether he or she can hear the distortion of the signal.

We can proceed in a similar way also in the case of practising the identification of noise in a recording. Noise simulation can be generated with a sound generator which can be mixed to the required audio recording in the multichannel mode of a digital audio workstation. Subsequently, the listener can determine the presence of noise in the recording again by manual assessment.
Ideally, training the right cutting of a musical recording should be done on audio materials that are the primary unedited recording containing all the disturbing elements. Such audio recordings are also available from educational websites such as mixwithmasters.com or puremix.net. These sites have archives of several multitrack projects of various genres and quality that are meant directly for practising editing and mixing.

Training should start with simple recordings of solo musical instruments or speech, with focus only on a homogeneous sound source. In the later phases of the training, multitrack recordings of pop bands or rock bands can be added, and advanced students can work on multitrack recordings of symphonic orchestras or choirs.

2 Conclusion

Perfecting the aural skills of those who want to work with sound on a higher level in terms of quality is one of the basic educational requirements. Currently, the diversity of the musical audio sources places large demands not only on sound engineers but also as on amateurs who work with sound only occasionally. The technical tools and their availability to a wide range of users offer enormous variability in terms of approaches and procedures in the post-production phase of audio recordings. The only common essence of all creative approaches to editing audio materials is the ability to assess the quality of an audio recording by ear, especially from the technical aspect.

Today, audio recordings are listened to on various devices, from loudspeaker sets up to mobile phones. Consequently, the demands on the aural quality of the audio recording keep increasing. Despite this trend, there are few tools to develop aural skills. And there are even fewer tools that are conceived in the right didactic way, so lecturers and teachers are left with alternative methods for ear training, which are difficult not only to prepare but also to implement.

Software with didactic focus on the development of aural skills, such as Train Your Ears or How to Listen! by Harmann, set the standard for modern education. Further, specially focused didactic software for training orientation in the dynamic range and the temporal spectrum should be developed based on these. Lastly, aural skills must be perfected even in terms of the technical quality of the audio recordings and there is no relevant educational software in this field.

The auditory system and its skills are the basic equipment and tool of a sound engineer to achieve his or her goals. These goals are mainly to achieve audio recordings of a balanced sonic quality, original sonority and technically correctly processed quality. Their training should therefore be one of the basic tasks in education.

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