

39

OPPORTUNITIES OF USING MOBILE APPLICATIONS BY STUDENTS IN THE FRAMEWORK OF TEACHING HUMANITARIAN SUBJECTS FOCUSED ON THE DEVELOPMENT OF SENSORY-PRACTICAL ACTIVITY

OPORTUNIDADES DE UTILIZACIÓN DE APLICACIONES MÓVILES POR PARTE DE LOS ESTUDIANTES EN EL MARCO DE LA ENSEÑANZA DE ASIGNATURAS HUMANITARIAS ENFOCADAS EN EL DESARROLLO DE LA ACTIVIDAD PRÁCTICA-SENSORIO

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ABSTRACT

The purpose of the study was to test the effectiveness, benefits, and specificity of using the Crazy Ootka Software's Perfect Ear program, designed for ear training. The research was carried out experimentally. The goal of the study is to test the effectiveness and identify the advantages and specifics of the Perfect Ear ear training program by Crazy Ootka Software. The experimental study includes four groups: professional and amateur musicians training with a teacher and using the mobile application, as well as students with and without music education using Perfect Ear independently with no pedagogical assistance. The study results demonstrate unquestionable effectiveness of the application used with a teacher's assistance among both professionals and amateurs, as well as when used by students without musical training independently under some additional conditions (the presence of basic knowledge of music theory, regularity of work, understanding of the capabilities of the program, etc.). The scientific novelty of the study is due to it providing the first evaluation of the application's effectiveness in musical ear training among people with different levels of training, as well as identifying the prospects for the implementation of the application in professional training and self-training by amateur musicians.

Keywords:

Solfeggio, computer technology, ear training, educational programs, electronic educational resources.

RESUMEN

El propósito del estudio fue probar la efectividad, los beneficios y la especificidad del uso del programa Perfect Ear de Crazy Ootka Software, diseñado para el entrenamiento del oído. La investigación se llevó a cabo de manera experimental. El objetivo del estudio es probar la eficacia e identificar las ventajas y especificidades del programa de entrenamiento auditivo Perfect Ear de Crazy Ootka Software. El estudio experimental incluye cuatro grupos: músicos profesionales y aficionados entrenando con un profesor y usando la aplicación móvil, así como estudiantes con y sin educación musical usando Perfect Ear de forma independiente sin asistencia pedagógica. Los resultados del estudio demuestran una eficacia incuestionable de la aplicación utilizada con la asistencia de un profesor entre profesionales y aficionados, así como cuando es utilizada por estudiantes sin formación musical de forma independiente bajo algunas condiciones adicionales (presencia de conocimientos básicos de teoría musical, regularidad de trabajo, comprensión de las capacidades del programa, etc.). La novedad científica del estudio se debe a que proporciona la primera evaluación de la eficacia de la aplicación en el entrenamiento del oído musical entre personas con diferentes niveles de formación, así como a identificar las perspectivas de implementación de la aplicación en la formación profesional y la autoformación por parte de músicos aficionados.

Palabras clave:

Solfeo, informática, entrenamiento auditivo, programas educativos, recursos educativos electrónicos.

INTRODUCTION

At all its levels, contemporary music education is not complete without computer technology. Music universities around the world deploy music and computer technologies, educational computer programs, and electronic content of disciplines (Anufrieva et al., 2022). The training process is growing to be more interactive, broad in scope, and accessible (Shukshina et al., 2022). Today, we can observe the synergy of musical art and computer technology, which is ubiquitous in the various creative processes associated with music (learning, creating, storing, transmitting, processing, reproducing) (Urmina et al., 2022). Digital technology is used by professionals and amateurs to record, arrange, edit, and play music and distribute it around the world (Pereverzeva, 2021). In addition, there are services like Mubert allowing to generate music in any style and genre using artificial intelligence and the popular Shazam application as a system that recognizes tunes within seconds.

At present, work on the development of a sense of rhythm and harmonic hearing, memory, and musical thinking utilizes information reference, training, control, gamified, and modeling programs. MuseScore, Impro-Visor, and Capella note editors have a built-in audio sequencer. Sheet music can be typed and edited using a computer mouse or MIDI keyboard (Gladilina et al., 2022). The written sheet music is then played thanks to the built-in audio playback program. Using note editors, a teacher can create custom musical fragments (interval and chord chains, one-, two-, and three-voiced dictations for aural analysis), edit, play, arrange them, and so on.

A musical ear refers to a person's ability to distinguish sounds by pitch and scale steps and determine the sound composition and qualities of intervals and chords, rhythmic patterns, and elements of the structure of music (Pereverzeva, 2020). It is essential for all types of music-making and requires extensive practice. The proper development of a student's musicality and musical ear quality promotes their career success as a music performer, composer, and teacher. The musical ear is developed gradually through melody singing, aural analysis of sound pitches, durations, rhythmic groups, harmonies, intervals, and chords, and recording dictations by ear. Ear development is a fundamental yet complicated and gradual step in the process of advancing one's musical abilities and developing professional mastery as a musician. Absolute pitch refers to the ability to determine the acoustic pitch of any sound regardless of tonality (Pereverzeva & Smirnov, 2017).

Developing the musical ear requires completing the tasks assigned by a professional teacher who plays certain notes, harmonies, rhythmic groups, intervals, and chords, selects musical dictations for aural analysis, and evaluates the results of a student's work (Gadzaova et al., 2022). However, specialized music computer programs for musical ear development can partially or completely substitute a teacher adjusting the training process based on a user's needs and tracking their progress precisely. Conservatories and university music departments start to implement licensed software for teaching music students, such as Ear Training for Musical Creativity (Improvise for Real, n.d.), Aural Test Training Programme (E-Music Maestro), GNU Solfege, Meludia, etc. Such programs can manage and control the process of musical ear development and even provide grades at the end of training.

The use of information technology for the development of the musical ear is currently one of the most prioritized directions in scientific research, methodical developments, and organization of training. The methodological basis for the present study is formed by research on music computer programs, methods of teaching solfeggio, and the development of the musical ear and the sense of rhythm.

In a study titled "Development and Validation of the Musical Ear Training Assessment (META)", A. Wolf & Kopiez (2018), explore the capabilities of Musical Ear Training Assessment in developing analytical auditory perception of music. The authors have "verified a one-dimensional test model using item response theory identifying the best 53 items to measure a person's ear training and analytical hearing skill" and "investigate a variety of moderator variables assumed to influence ear training skill for advanced music students and musicians". A study by Kim & Song (2008), aims *"to develop an ear training system whereby beginners or children can learn music with ease in terms of computer access which is part of their daily life."* Serdaroglu (2018), in the article "Ear Training Made Easy: Using IOS Based Applications to Assist Ear Training in Children" presents the results of a study on the use of ear development programs. The author examines how "several IOS based ear training applications will be evaluated considering the target group, children between ages 6-11. The possible effects and incorporation of these applications into the classroom and private studios will be discussed. Each application will be evaluated on several components; the ear training modules, user-friendliness, possibility of the evaluation of students' progress by the teacher and probable reaction of the children to these applications". The practical implementation of computer technology in music education and music composition is addressed in the works of Pereverzeva (2021).

The authors study the opportunities and prospects of the use of ear training applications in teaching children since it is expedient to train the musical ear from an early age (Stanca et al., 2020; Kutepova et al., 2022). However, today's reality is that people begin to engage in musical creativity in adulthood, and future entertainers and theater and film actors have to train their musical ear at the university when receiving vocational training indirectly related to musical art (Chumaceiro Hernandez et al., 2022). It has not yet been studied how effective is the use of ear training applications by amateur musicians and with no pedagogical assistance and basic music education and the Perfect Ear application, in particular, has not been assessed from the viewpoint of a practicing solfeggio teacher working with students at different levels of musical training.

The object of our attention is the educational combined programs of mobile applications designed for training the main types of aural skills: harmonic, rhythmic, melodic, and mode and tone. The study aims to test the effectiveness and determine the advantages and specifics of using the Perfect Ear program by Crazy Ootka Software. The effectiveness of the application when used by professional and amateur musicians independently and with pedagogical supervision is tested experimentally. The study hypothesis suggests that the application is effective for ear training for users of all levels, but the best results are achieved through work with the application under the guidance and supervision of a teacher, as well as with regular training and utilization of all features of the application.

MATERIALS AND METHODS

The research is experimental. Among the ear training programs in use today, including Ear Training for Musical Creativity, Aural Test Training Program, EarMaster, GNU Solfege, and Meludia, we chose Perfect Ear for the following reasons:

- it is a free application that any student can download;
- the application has a clear interface and is easy to use;
- students can engage in ear training using their phones without purchasing computers or tablets;
- the program contains all the basic exercises that students need to do in class and at home.

The study of the prospects of the application in ear training is based on theoretical and empirical methods including analysis of scientific research and results of empirical studies; analysis of musical ear training programs and applications from the point of their functionality, capabilities, and learning outcomes; assessment of the level of musical ear development in the experiment participants (a total

of 80 people) through testing (identifying the elements of music by ear); practical implementation of the Perfect Ear application in a solfeggio course with students and studio participants with and without music education to test the effectiveness of the application for a wide range of users; assessment of the experiment participants' level of musical ear development after the experimental work through testing.

The study, conducted in the academic year 2020-2021 (September 2020 – May 2021), involved four groups: professional musicians (22 1st- and 2nd-year students of the Russian State Social University music faculty) and amateurs (18 participants of the musical and theater studio at the Russian State Social University) who studied solfeggio both with a teacher and with the help of the application, as well as students with music education (16 students of the "Music Educator" direction of training) and without music education (24 students of the "Social and Cultural Activity" direction of training) who used Perfect Ear on their own with no pedagogical assistance.

The analysis of scientific research and the results of empirical studies is required to determine the extent of research on the topic. It has been found that the Perfect Ear mobile application had not been mentioned in recent research or subjected to scientific examination. The analysis of ear training programs and applications in terms of their functionality and training opportunities is conducted to compare various programs and applications, evaluate the prospects of the given product, and determine the advantages of the application under study.

The practical implementation of the Perfect Ear application through incorporating tasks and exercises from the application into a solfeggio course is required to test the program's effectiveness in musical ear training among users at different levels of training (students who had musical training prior to university and those with no basic knowledge in music theory), as well as to compare the effectiveness of the program when used with and without a teacher's assistance.

The work involved several stages: the study of research and methodological literature, analysis of the functionality of ear training programs and applications, comparing the capabilities and identifying the advantages of the programs, as well as experimental work with the RSSU students and studio participants from different directions of training and at varying levels of musical training aimed at assessing the application's effectiveness (practical pedagogical work on improving the level of musical ear development based on using Perfect Ear).

As a part of the experimental work, the experiment participants' (80 people in total) level of musical ear development was assessed through testing, which includes 10 tasks of identifying the elements of music by ear – steps of major and minor, types of harmonies, intervals, chords, tonalities, repeating rhythmic patterns, melodic phrases, singing a one-voiced melody from the sheet and writing a one-voiced dictation by ear.

The diagnostic stage of the study involved assessing the students' harmonic, melodic, mode and tone, and met-rhythmic aural skills. The study participants including 1st- and 2nd-year students of the Russian State Social University music faculty (group 1), 18 participants of the musical and theater studio at the Russian State Social University (group 2), 16 students of the “Music Educator” direction of training with basic music education (group 3), and 24 students of the “Social and Cultural Activity” direction of training with no prior music training (group 4), were asked to determine different types of harmonies, intervals, and chords by ear, identify the tonality of 5 sounding pieces, write a one-voice dictation, and sing an 8-tact melody from the sheet clearly intoning and performing the given rhythm. The results of the auditory analysis tasks allow dividing the study participants into the groups of high, average, and low development of the musical ear. The low results are demonstrated by the students who were unable to determine most of the types of intervals, harmonies, and chords by ear and correctly identified one or none of the tonalities of the played pieces. The average results are demonstrated by the students who identified some types of intervals, harmonies, and chords, and 2–3 tonalities. The high results are demonstrated by the students being able to identify almost all types of intervals, harmonies, and chords and 4 or all 5 tonalities by ear.

The results of the experiment indicate that out of 22 students in group 1, 40% (10 people) initially were at the low level of ear development, 50% (11 people) were at the average level, and 5% (1 person) was at the high level. In group 2 (18 amateur musicians), 75% demonstrated the low level of musical ear development, 15% were at the average level, and 10% were at the high level, which is not surprising given that the participants in this group had not studied music and solfeggio. 16 students of the “Music Educator” direction of training having music education (group 3) demonstrated results similar to group 1: 40% of students were at the low level, 40% – at the average, and 20% – at the high level of musical ear development. Finally, 24 students of the “Social and Cultural Activity” direction of training with no prior musical education showed results close to group 2, since they also had no experience of musical training: 80% of the students at the low

level of musical ear development, 15% – at the average level, and 5% – at the high level.

These results demonstrate the need for the improvement of the musical ear in all four groups since all of the RSSU students were studying music performance disciplines (instrumental music and academic or pop vocal) as part of their training programs. Throughout the 2020-2021 academic year, the students in four groups were completing exercises, engaging in musical ear training, intoning sheet music, and writing aural dictations using the Perfect Ear application. The first two groups used the application under the supervision of a teacher and continued to study solfeggio while groups 3 and 4 studied only through the application (under the conditions of distance learning due to the COVID-19 pandemic, work with the application was a forced measure in part, however, both groups of students were studying part-time, therefore, self-study prevailed among them).

In addition, only 3 students out of 80 participants in the experimental work were found to have the absolute pitch or being close to it. The goal of further work, the formative stage of the experiment, was then to implement the Perfect Ear application in practice at solfeggio lessons with the four student groups throughout the academic year.

RESULTS AND DISCUSSION

Perfect Ear for Android is a specialized application for improving knowledge of music theory and training the musical ear. The mobile program presents a modern encyclopedia of music that allows a user to become almost an expert in the basics of music (scales, intervals, chords), improve their sense of rhythm, increase the speed of reading sheet music, and advance the existing skills related to understanding music and sound. Aside from theoretical tasks, the application provides for practice and a variety of exercises. For example, a user is required to complete tasks in a certain period be able to read the notes, find a sounded chord, play a given rhythm, or make marks of positions on the guitar fingerboard.

The application provides the following functions and sections:

- theoretical articles;
- special customizable simulators for identifying intervals, scales, chords, and rhythmic groups by ear;
- an editor of scales, chords, and entire chord sequences for completing practical assignments;
- writing musical dictations by ear and checking the correctness;

- reading sheet music;
- training the absolute pitch through identifying individual notes;
- solfegging melodies;
- a dictionary of scales, chords, and intervals.

The application is equipped with a clear and understandable interface, is continuously developed and updated, and is successfully tested by teachers and musicians around the world (to date, the application has over 5 million users). The assessment of the program's effectiveness as a part of solfeggio lessons was conducted based on these facts. During the 2020–2021 academic year, the students of all four groups were using the Perfect Ear application, moreover, the first two groups training with pedagogical guidance used the functionality of the program in full, while the other two groups training independently only used individual functions, specifically:

- the collection of articles on music theory was used by the experiment participants in the process of mastering the solfeggio discipline and studying the topics of the course (harmonies, intervals, chords), which was necessary to structure the knowledge of the subject and ensure quality performance of exercises;
- the dictionaries of scales, intervals, and chords provided the opportunity of singing the scales, interval, and chord sequences for later identification by ear and solfegging;
- the trainer for pitch, harmonic, and melodic aural skills is the main feature of the application that allowed the students to train in auditory analysis and clean, error-free intonation (since every phone has a built-in microphone, the program can record the voice without extraneous noise and determine the purity of intonation);
- a trainer for the sense of rhythm comprises exercises in identifying, repeating, and memorizing rhythmic patterns and complex shapes and allows visually assessing the correctness of performance and adjusting to the beat of the built-in metronome;
- melodic dictation in different keys and different levels of difficulty is played through speakers (better to use a headset) and written down by a student, and then the correctness of the notation or a student's vocal performance of the dictation melody is checked by the program (dictations can be assigned by a teacher indicating the number, so the student does not see the notation before listening to dictation, just like at a solfeggio lesson);
- sheet music reading simulator offers sheet music pieces of different difficulty levels to be sung or played on

an instrument; the program records the performance and indicates the notes or pieces performed incorrectly in red on the screen;

- performance evaluation and statistics – a system for monitoring the results of exercise performance and tracking the progress in the musical ear development (the program updates the data after each exercise and the student and the teacher can visually see the progress of training in the daily statistics).

The members of the first two groups, professionals and amateurs who studied solfeggio with a teacher weekly, were reinforcing the skills of aural analysis and writing dictations by doing exercises in the Perfect Ear application as a solfeggio homework assignment. For each student, the teacher was selecting the set of tasks, levels of difficulty, and class frequency ranging from daily in-app sessions to several tasks per week. Participants in the second group, non-musicians attending the RSSU theatre studio, were studying the material from the theoretical block before completing the exercises to not struggle with tasks involving aural analysis of scales, scale steps, intervals, and chords.

The members of groups 3 and 4, music students and future specialists in social and cultural activities, were training in the application independently and received assignments from the teacher remotely since they were studying part-time. Group 3 faced no problems completing the exercises as its members had basic music training and used, while participants in group 4 not having musical training were poorly oriented in the theoretical material and practical tasks, so they performed them irregularly and limited the use of the application functions to the simulator for the pitch, harmonic, and melodic aural skills and the simulator for the sense of rhythm. The non-musician students were thus unable to master the material and train in the application to the full without a teacher's assistance.

At the control stage of the study, at the end of the academic year, the levels of development of the harmonic, melodic, mode and tone, and metrythmic aural skills were once again assessed in all four groups. Assessment of the musical ear development level was also carried out by the method of auditory analysis – identification of intervals, harmonies, chords, and tonalities by ear, writing dictations, and solfegging. The results of auditory analysis tasks show that out of the 22 members of group 1, 55% have increased their level of ear development up to the average, 35% – have reached the high level, and 10% demonstrate the low level. The use of the application by music students with pedagogical guidance proves to be quite effective. The results of group 2 (18 amateur musicians)

are more modest: 40% of the students are found to be at the average level, 35% are at the low level, and 25% show the high level of musical ear development, however, even this result also testifies to the effectiveness of the application for musical ear training among non-musicians starting to study solfeggio.

Group 3 comprised of 16 students of the “Music Educator” direction of training with prior music education demonstrate results similar to group 1 with 60% of the students being at the high level of ear development, 30% being at the average level, and 10% being at the low level. Even in the absence of lessons with a teacher, training in the application and continuing to develop their musical ear and maintaining it at a proper level is found to be useful for music students. Finally, group 4, 24 students of the “Social and Cultural Activity” direction of training with no music education, also show results that indicate the effectiveness of them using the ear training application even without pedagogical assistance and supervision: 35% of the students are at the average level of ear development, 40% are at the low level, and 25% are at the high level.

Music educators today use a variety of information and communication technologies designed for musical ear development. There are free programs and applications for smartphones available online (Table 1). The study by Kim & Song (2008), indicates that *“ear training with computer system is devised so that children can practice ear training easily; this system is also beneficial to others who plan to major in music.”* However, each program has its advantages and drawbacks and, as stressed by researchers, their effectiveness is supported by certain conditions (Thraves, 2018).

Table 1. Free programs and applications for smartphones available online.

Vocalist Lite (for Android)	Has a game form, several levels of difficulty. The application plays a melody depending on the difficulty level, and the user sings it. The number of points depends on how accurately the student intones. The application is ineffective in ear development, as it only helps to understand how accurately the user gets to the notes. Recommended for learning to sing simple melodies only at the initial stage of learning music. However, with regular practice, the app can improve one's ear development.
Perfect Pitch (for Android)	The game is intended for mastering musical notation and developing musical memory. A tuning fork appears on the smartphone screen, which emits a sound, and the user must press the corresponding key. The app is useful for developing a child's ear for music but not for teaching students.

Voice Training (for Android)	The user presses a key on the piano keyboard on the phone screen and repeats a note using their voice, and the application confirms the accuracy or inaccuracy. The program does not have a user-friendly interface but there is a built-in tuner that shows the level of overestimation or understatement of the sound sung by the user. The user can sing single notes or phrases.
Functional Ear Trainer (for Android)	The application allows one to develop the ear for music by distinguishing between intervals in different keys and contains various kinds of exercises, including determining the functions of steps and chords in a scale. The program is useful for ear training for vocalists who have basic musical education and understand the terms.
Vanido (for iPhone and Android)	The application allows one to determine the range of their voice, offers many chants, and shows a diagram of the sound of the voice on the phone screen, allowing the user to understand how accurately they sing. The daily activity reminder function is also useful.
Yousician (for Android)	The program teaches singing or playing a musical instrument of the user's choice (guitar, piano, ukulele, double bass). It has the function of reminding the user about the lessons and makes it possible to sing to the “backing track” and in different rhythmic versions. The repertoire includes famous musical hits of the 20th-21st centuries. Tasks are differentiated by difficulty levels, many have a game form. The application is paid.
EarMaster	Musical program launched in 1996 by a Dutch company Miditec (since 2005, the program has been titled EarMaster ApS). The program is focused on training the musical ear and the skill of singing from sheet music and mastering the theory and practice of solfeggio. EarMaster presupposes training completely independently from scratch and provides for a user reaching a level of general musical development sufficient for amateur musicianship, as well as the development of music performance and composition skills in performing and composing music. In 2014, the program was upgraded and adapted for use by music school teachers, choir directors, and private teachers, as well as entertainers, actors, and any other person wishing to train their musical ear and learn to sing, play, and compose music. The latest versions of EarMaster are currently used by educational institutions, for instance, by Berklee College of Music in the United States. EarMaster provides several training modes: professional with progressive music theory and ear training courses and amateur with a beginner course. The material for auditory analysis covers various genres from classical music to jazz. A user can customize the mode and level of training for their practice. The provided exercises involve singing, identification and comparison of intervals and chords, their inversions and sequences, durations and rhythmic groups, reading from the sheet, repeating a given rhythm, searching for rhythmic errors, single and multi-voiced melodic dictations, and test tasks. The program provides a large array of instruments and a functional MIDI keyboard with scale steps, alphabetic (C, D, E...) and syllabic (do, re, mi...) notation of notes, a microphone, and a note editor and recorder. The task completion results are presented on the screen and can be displayed to the solfeggio teacher.

Ear Training for Musical Creativity	The program by David Reed (2019) is a step-by-step ear training system for a wide audience that focuses on users' self-training for further amateur music-making – singing, playing musical instruments, and composing simple compositions. The training course is described in detail and implies gradual learning that involves auditory analysis, identifying various elements of music by ear (from the simple to the more complex), and singing individual notes, major and minor steps, melodies, intervals, and chords. The program requires basic knowledge in music theory, which means that it is not as effective without basic music education or pedagogical support. The advantages of the program include the prevalence of active music practice and opportunities for ear training, learning a musical instrument, and actualizing one's creative abilities.
Aural Test Training Programme	Programme comprises auditory analysis and testing tasks and claims to provide a substitution for a professional teacher. It also presupposes gradual ear training: a cycle of lessons is divided into two blocks with four levels in each (1–4 and 5–8) and includes all necessary elements (music theory articles, dictionaries, an entire solfeggio textbook, educational tasks, exercises, and practical lessons, test assignments, a synthesizer with a MIDI keyboard, and a blog of the authors and tutors of the program). The program is developed by specialists in music, pedagogy, information technology, and cognitive psychology Sandy Holland, Peter Noke, and Janet Noakes.
GNU Solfège	Free ear training program developed by Python focused on helping musicians to improve their aural skills and knowledge in music theory. The program allows its user to adjust the offered exercises or create custom ones and is, therefore, intended for people with basic solfeggio skills. The exercises involve auditory analysis, comparing, and singing the assigned melodic and harmonic intervals, identifying and singing chords, harmonies, and their steps, melodic and rhythmic dictations, memorizing rhythmic patterns, theoretical questions and tests, and the intonation of melodies, interval, and chord sequences.
Meludia	French interactive educational online platform for studying the basics of music theory. It provides a cycle of progressive interactive exercises for training the musical ear and memory that involve the emotional and analytical perception of music and musical means of expression – rhythm, space, dynamics, form, timbre, melody, and harmony. Meludia is officially implemented by the Curtis Institute of Music in Philadelphia, as well as educational institutions in Estonia, Malta, and Canada. In 2014-2015, Meludia won the Gold Medal and Grand Prize at Concours Lépine for Innovation, the Gold Medal and Grand Prize at the European Competition for Innovation, the Grand Prize for Cultural Innovation at Fabfest Paris, the Interactive Innovation Awards in Austin, and more.

The programs discussed above are primarily intended for future professional musicians and, therefore, require basic theoretical knowledge and pedagogical assistance while using it independently as an amateur musician would be difficult and mostly ineffective. The advantages of the Perfect Ear program are apparent:

- the program is free and smartphone-friendly;
- the combined program comprises various forms of work in solfeggio lessons and contains theoretical material, musical ear training exercises, and various test systems allowing to study without a teacher;

- the provided simulators can be adjusted to the available knowledge and skills of a user (a professional musician or an amateur);
- the exercises vary by levels of difficulty and types of aural skills;
- the interface is simple and clear;
- the program versions are continuously updated considering users' needs;
- the program allows for ear training in any place at any time and accounts for the specific characteristics of perception and memory (it is most effective to rehearse and reinforce the material repeatedly throughout the day).

During interval training, the application visualizes the purity of the sung intonation by displaying a diagram and a moving arrow on the screen. People who have the absolute pitch can practice identifying the key pitch of an unfamiliar musical passage, singing different musical tones, identifying the pitch of sounds produced by a musical instrument, and determining the approximate pitch of a non-musical sound (noise). Thus, the application is designed for training the musical ear at a high level up to the absolute pitch and not only for professional musicians but also for amateurs who can study on their own.

CONCLUSIONS

The conducted experimental study confirms the hypothesis that the use of the Perfect Ear mobile application at university solfeggio lessons is effective among both music students and amateurs and both with pedagogical guidance and when used in self-training at home. It is advised to be used by students both in the classroom and at home on their own. The advantages of using information and communication technologies in music education include:

- person-oriented approach in training;
- effective mastery of the material;
- access to large volumes of information;
- opportunities for self-training and self-assessment;
- saving training time;
- activation of psychological processes (attention, perception, memory, imagination, etc.).

It should be additionally noted that, nevertheless, the greatest results are achieved by students who have basic knowledge of music theory or make use of the entire functionality of the program from a music theory textbook to writing musical dictations. Thus, musical ear development calls for stage-by-stage and systemic training in

which the mobile application cannot substitute a teacher completely but does provide assistance in advancing one's musical abilities to both professional musicians and amateurs. The application can be equally useful for beginners who have no musical experience, as well as for professionals wishing to improve their knowledge and skills. Perfect Ear may also be of use to music teachers as additional support in training students.

Limitations of the study are associated with the fact that the experimental work considers not all of the factors that could have affected the learning outcomes. It is also expedient to assess the capabilities of the program in the development of absolute pitch which will require a much more long-term experimental study.

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