FONASKEIN: AN INTERACTIVE SOFTWARE APPLICATION FOR THE PRACTICE OF THE SINGING VOICE

Fotios Moschos
University of Athens,
Department of Pedagogy,
Athens, Greece
fotmos@windowslive.com

Anastasia Georgaki
University of Athens,
Department of Music Studies,
Athens, Greece
georgaki@music.uoa.gr

Georgios Kouroupetroglou
University of Athens,
Department of Informatics and Telecomunications
Athens, Greece
koupe@di.uoa.gr

ABSTRACT

A number of software applications for the practice of the singing voice have been introduced in the last decades, but all of them are limited to equal tempered scales. In this work, we present the design and development of FONASKEIN, a novel modular interactive software application for the practice of singing voice in real time and with visual feedback for both equal and non-equal tempered scales. Details of the Graphical User Interface of FONASKEIN are given, along with its architecture. The evaluation results of FONASKEIN in a pilot experiment with eight participants and four songs in various musical scales showed its positive effect in practice of the singing voice in all cases.

1. INTRODUCTION

Singing practices in Modern Greece have a long history and display great diversity. Its roots go up to the interpretation of ancient Greek music which is considered as the theoretical fundament of Western music. The mathematical structure of Ancient Greek Music as referred to the works of Archytas, Philolaos, Didimos, Eratosthenis, Ptolemeos, and Aristoxenos still fascinates many researchers all over the world [1]. This written and oral tradition has been transferred to other types of music through the centuries such as the written theory of Byzantine music [2], the oral tradition of Greek folk music and even Rebetiko.

These unique characteristics of the diverse singing styles in Greece along with their mathematical relationships can be described in a generative way using the well-tempered tuning system; this causes confusion between the oral tradition and the music notation. Many of these different singing practices are carried out in Greek schools via traditional notation; the problem is that the teaching approach does not take into account the different tuning systems [3]. In this way the singing culture of children is still conflicted and depends on the cultural background of their family and the place of origin.

Although a number of visual feedback software applications for singing have been introduced in the recent years, non–equal tempered music scales are not a common feature of these software packages.

In this paper, we present the design, development, and evaluation of FONASKEIN, a novel modular interactive software application for the practice of singing voice in non-equal tempered scales.

2. STATE OF THE ART ANALYSIS

2.1 A quick Overview

One of the first attempts at designing software for the practice of the singing voice appeared in 1985 from G. Welch [4] who developed an innovative application for the BCC Microcomputer called SINGAD. SINGAD produced musical notes one-by-one, by recording the user's voice and analysing the recordings. The application compared the fundamental frequencies (F0) of the two signals and displayed the results on the screen.

At the beginning of the 1990s, Welch and his team improved this software and ran it on the Atari platform by improving it in three ways. First, instead of only comparing the fundamental frequencies of the two audio signals, SINGAD also compares the whole pitch contour which was more accurate. Secondly, SINGAD could play audio via MIDI synthesizers or sound from General MIDI (like piano or flute. Finally, the graphical user interface was made friendlier to musicians by including a viewer for the musical notes.

Another software application that was developed by Rossiter and his team in 1996 is called ALBERT [5]. Except the voice training, ALBERT included the monitoring of the laryngeal action. The system provided a greater variety of visual feedback by displaying the parameters F0, CQ (larynx closed quotient), spectral ratio, SPL (amplitude), shimmer and jitter. ALBERT was used in some studies in order to identify the quality of voice production during visual feedback implementation, and could measure the pattern of change during a training lesson.

Eight years later, in 2004, Callaghan and his team developed SING&SEE [6], one of the most popular applications for the analysis of the singing voice with real time visual feedback (VFB). The main features of this research were the investigation of acoustic analysis technics, methods of displaying visual feedback in a meaningful way and the pedagogical approaches for implementing visual feedback technology into practice. Three parameters were distinguished as relevant for usage in the singing studio: pitch (F0 against time), vowel identity (R1, R2), and timbre (spectrogram). The major difference from previous studies was that not only quantitative but also qualitative data were of interest in this development.

In the same year, 2004, Welch and his team introdused a new project called VOXed. In this project Welch introduced the WinSINGAD [7]. The project also incorporated real-time VFB for singing education applications. While SING &SEE places emphasis on maximizing VFB technology itself, VOXed was aimed at maximizing the collaboration between different scientific fields. Psychologists, voice scientists, singing teachers, and singing students joined to form an interdisciplinary research team working for a better insight on the impact of VFB on the learning experience. Importantly, VOXed sought to work with participants as active agents rather than just passive recipients. The goal of the project was to investigate possible useful forms of VFB with the use of commercially available visual feedback software.

Another approach is the innovation of the MiruSinger software application developed by Nakako and his team [8] which introduced the possibility for the user to use an audio CD as a sample for comparison. MiruSinger analyzes the voice of the user, but also analyzes the voice from the song from the audio CD. Thus, it compares the audio signals from two human voices and not the human voice with a synthesized vocal sound. Nakako aimed to develop a software package for voice training with visual feedback with characteristics like tone accuracy, tempo, voice quality and expressive techniques (vibrato).

Lastly, the commercially available freeware Singing Coach[1] has been used in a number of studies in order to investigate children's voice profiles in a real educational environment; it has been tested in various countries and in Greek elementary schools where a computer-based vocal instruction methodology for music education has been proposed [3].

2.2 Critical approach

We appreciate that in the last thirty years there has been rapid evolution concerning the functionality and the incorporation of new parameters into the design of applications for the practice of the singing voice. For example, SINGAD uses only one parameter which is the detection of the fundamental frequency. ALBERT exploited the ever-increasing memory made common by the rapid development of personal computers in the 1990s. Furthermore, the advancement in combining different parameters for targeting different practices, such as singing and speech therapy has concretized the design of the software. SING&SEE mainly focused on aspects related to the same singers: fundamental frequency, identity vowel, and spectrogram. Then, the VOXed project introduced the WinSINGAD, which essentially combined the research parameters with those required by the musicians, namely the waveform, the fundamental frequency, various types of spectrograms in real time. Moreover, information captured by a camera was introduced for immediate feedback on the user's posture [9]. MiruSinger was considered innovative because it combined two real human voices with a reference to a voice recording from a commercial CD. Last, the Singing Coach software is more accessible and user friendly for children.

In general, optical feedback parameters have become more versatile and interdisciplinary over the years. Thus, these ameliorated software design principles opened access to a wider range of users. For example, SINGAD, in a first step has ben designed specifically for the development of children’s voices, where ALBERT has been designed for wider applications and is not only for use in music education, SING&SEE and WinSINGAD have been specifically designed for singers of all ages and levels. Finally, all of them are being used by a variety of target groups.

3. THE FONASKEIN APPLICATION

FONASKEIN is a software application for real-time analysis of the singing voice with visual feedback. While the existing applications are limited to only two western scales (major and minor scales), FONASKEIN for the first time introduces the possibility to study and practice with non-equal tempered scales, such as the Byzantine or the ancient Greek scales. It also offers the user the option to enter a scale that is not included in the above or even to "build" their own scale. This can be achieved thanks to an "alteration mechanism" of each of the 12 notes to three semitones using cent resolution.

3.1 Design and Graphical User Interface

FONASKEIN was designed and implemented in Max/MSP. Thus, its GUI presented in Figure 1 was designed with the capabilities of Max/MSP and includes seven different windows.

The first window is the main bar at the top of the screen. It can hide or unhide other FONASKEIN’s windows.

The second window is the audio control window. It is located on the left side of the screen. In this window, the user can control the audio input and output. Additionally, they can choose whether to record their voice or preview a prerecorded sample. Furthermore, the user can control the audio signal level both during both playback and recording.

The third window is the tuning window located on the right side of the screen. It includes an automatic tuner that indicates the deviation of the note that the user sings using a color scale.

[1] http://singingcoach.com/

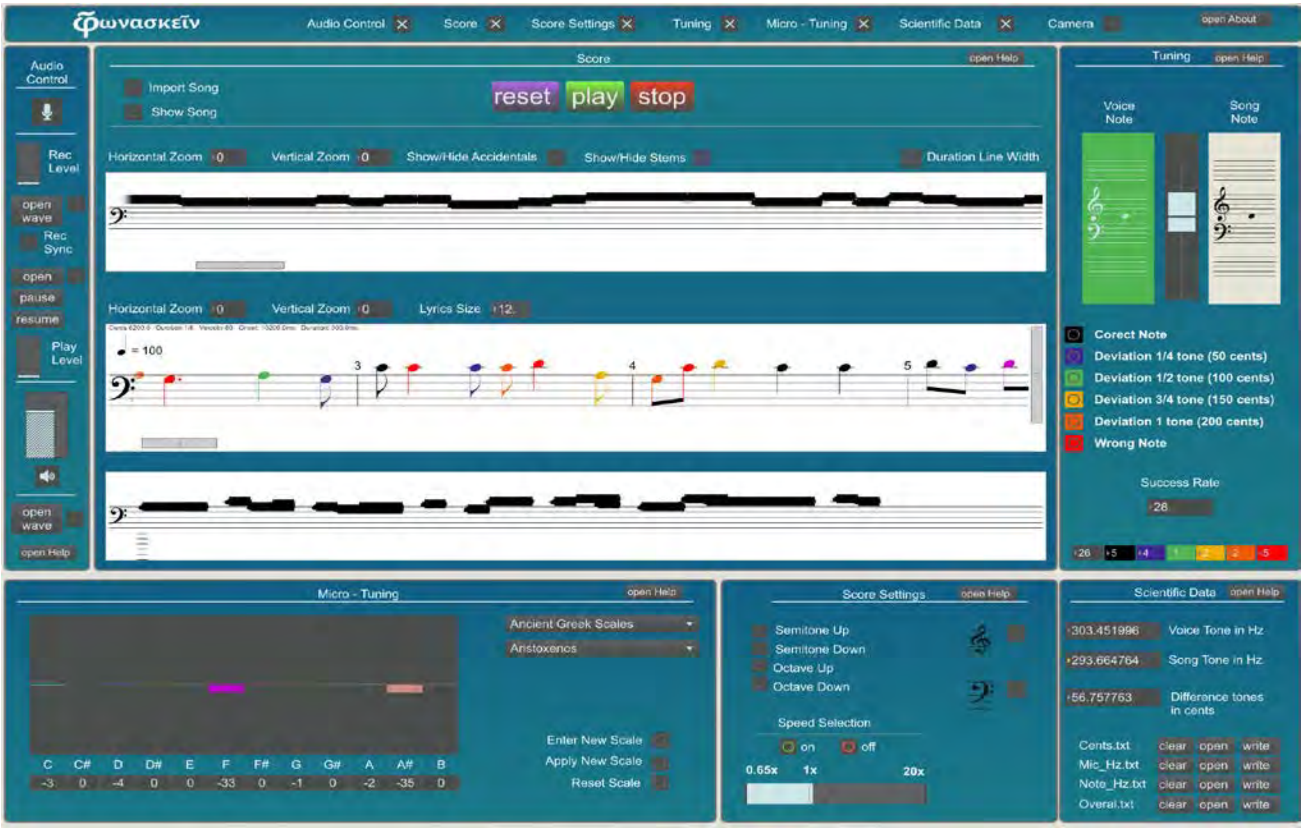


Figure 1. The Graphical User Interface of FONASKEIN.

The fourth window, the score window, is one of the most important windows. It is located in the middle of the screen and has two functions: a) it includes the main control buttons reset (play and stop). b) it presents three score windows where the user can read the musical piece with a piano roll view, regular view or see what they sang.

The next three windows are in the bottom of the screen and their main functions are the settings of FONASKEIN.

The window on the left side of the screen is a micro-tuning window. In this window, the user can select one of the default scales. There are three categories of scales, Western, Byzantine and Ancient Greek. Each of these has its own subcategories. The user can also import his/her own musical scales by writing the deviation of each note in cents under the multi-slider. FONASKEIN gives the user the possibility to play the song in these microtonal scales and listen to the correct musical intervals.

The next window is the score settings window. It is located in the middle of the screen and has three functions. The first one is the possibility to transpose the song a semitone lower, a semitone higher, an octave lower and an octave higher without affecting the micro tuning. The second possibility is to change the song's clef depending on the user's voice (bass clef for basses and tenors and treble clef for altos and sopranos). The last function is the speed selection, where the user can choose the speed of playback.

The last window is the data window which shows the current frequency that the user is singing, the current frequency of the correct note and the deviation in cents. The user has the possibility to view and save these data as *.txt files.

3.2 Architecture

The core of FONASKEIN comprises two parts. The first is related to the analysis and transformation of sound from the microphone signal and the second is dedicated to converting the MIDI file to a score as well as the import, playback, and control of microtonal scales.

For the first part, we used a Max Object called fiddle~. The operation of the algorithm of fiddle~ is based on the number of peaks of the audio signal where each one finds the tone of height and intensity. Specifically, the incoming signal is broken into segments of N samples with N a power of two typically between 256 and 2048. A new analysis is made every N=2 samples. For each analysis, the N samples are zero-padded to 2N samples and a rectangular window Discrete Fourier Transform (DFT) is taken using a rectangular window [10].

The next step is to calculate the frequency F0. Fundamental frequencies are guessed using a scheme somewhat suggestive of the maximum-likelihood estimator. The "likelihood function" is a non-negative function L(*f*), where *f* is the frequency. The presence of peaks at or near multiples of *f* increases L(*f*) in a way which depends on the peak's amplitude and frequency as shown:

$$L(f) = \sum_{i=0}^{k} a_i\, t_i n_i$$

where k is the number of peaks in the spectrum, a_i is a factor depending on the amplitude of the ith peak, t_i depends on how closely the ith peak is tuned to a multiple of *f*, and n_i depends on whether the peak is closest to a low or a high multiple of *f* [10].

The next step to build the FONASKEIN was the GUI score component. The Max/MSP does not support embedded objects with the creation pentagram, of notes and general notation. For this reason, we used not only an object designed by an external programmer, but a whole library comprising a large number of objects, the *bach library*.

The *bach library* is a cross-platform set of patches and externals for Max, aimed to bring the richness of computer-aided composition into the real-time world. In addition to that, it includes a large collection of tools for operating upon these new types and a number of advanced facilities and graphical interfaces for musical notation, with support for microtonal accidentals of arbitrary resolution, measured and non-measured notation, rhythmic trees and grace notes, polymetric notation, MusicXML and MIDI files [11].

As already stated, *bach* is a library of objects and patches for the software Max/MSP. At the forefront of the system are the bach.score and bach.roll objects. They both provide graphical interfaces for the representation of musical notation: bach.score expresses time in terms of traditional musical units and includes notions such as rests, measures, time signature, and tempo; bach.roll expresses time in terms of absolute temporal units (namely milliseconds), and as a consequence has no notion of traditional temporal concepts: this is useful for representing non-measured music, and also provides a simple way to deal with pitch material whose temporal information is unknown or irrelevant [12].

3.3 Non-equal tempered scales

One of the important novel features of FONASKEIN is its ability to import micro-tunings for singing in the Greek language. For the first time, the user is able to listen to a song that is written on a different scale from that of western music while he can exercise his voice on these interstices.

FONASKEIN, as mentioned above, includes a field with twelve sliders, one for each note. The sliders are able to move ± 300cents that can vary each note by three semitones. When the user presses the *Apply New Scale* button, a simple yet lengthy process allows the introduction of interstices of the two graphical objects of the *bach* library.

When the user changes the slider of a note by x cents, then the program will have to move all those notes in all octaves by the same distance. To do this it needs to follow a series of steps. The first step should be to choose the notes. After that, a second instruction enters the change of the note. This command is Cents = Cents + X. In this way, all selected notes have changed by the same pitch with cent accuracy. The time it takes FONASKEIN to do this is just 94 milliseconds, which is less than 1/10 of a second.

4. EVALUATION METHODOLOGY

The goal of the evaluation is to measure the change of the tonal errors in a singing voice by a number of participants after they practice with FONASKEIN in four songs with different music styles. The first song selected was "Ta paidia kato sto kampo" of Manos Hatzidakis (S1), a song written in the Western scale. The second song, "Thalassaki", is a song in the Greek tradition scale Dorios (S2). The third song, "Apolitikion tou Staurou", is a Byzantine hymn written in the First Mode (S3) and the last song, "Epitaph of Seikilos", is an ancient Greek hymn written in 2nd century B.C. (S4). Eight postgraduate students of the University of Athens participated in the evaluation experiments. Among them, four were male and four female. Half of them were musicians.

The applied procedure follows the educational/training scenarios approach which is appropriate in testing computer-based tools in learning [13]. The educational scenario takes place through a series of educational activities. The structure and flow of each activity, the role of the learners in it and their interaction with the interactive software are described in the context of the scenario [14].

Two activities were included in our evaluation scenario, each with two tasks. In the first one each participant received four audio files made using FONASKEIN that correspond to the first seconds of the songs S1, S2, S3 and S4. The participants had to study themselves for a period of one week how to sing these songs, without any help. During the next task of this activity each participant sang the four songs he/she studied and the researcher digitally recorded their voices in a studio. Then the recordings were analyzed by FONASKEIN and the measured tonal errors constitute the comparison basis before the participants used FONASKEIN for training.

In the second activity the participants were asked to practice the four songs using FONASKEIN for the same period of one week. They fully exploited both its features of micro-tuning and the capability of visual feedback in real time. During the second task participants sang the four songs using FONASKEIN.

Finally, the participants completed a questionnaire with their demographic details, included both their cultural background and their relationship with the music and the four songs.

5. RESULTS

The analysis of the measurements in both activities was based on the following number of notes for each of the four songs: S1=61, S2=49, S3=66 and S4=37. We used MS-Excel 2010 for all the statistical analysis of the measurements.

Figure 2 presents for each one of the four songs S1-S4 the average of the positive and the negative errors in cents for all the participants and for all the notes for the two activities, i.e. before (b) and after (a) using FONASKEIN for the training of their singing voices, along with the standard error of the mean.

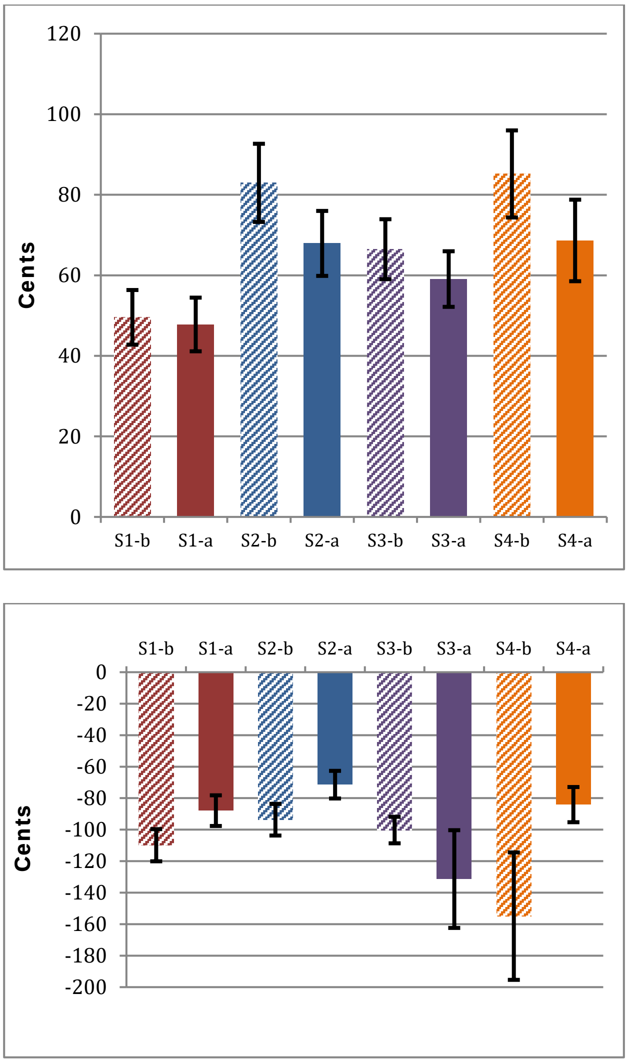


Figure 2. Average positive (above) and negative (bellow) errors in cents, for all the participants and for all the notes, before (b) and after (a) using FONASKEIN.

The number of negative errors was larger for all the songs. We observe a positive effect on using FONASKEIN as the number of errors was reduced in all the cases of the songs S1-S4. The largest improvement was for S4 (71 cents for the negative errors and 17 cents for the positive errors). The smallest improvement was for S1 (22 cents for the negative errors and 2 cents for the positive errors).

Figure 3 presents for each one of the four songs S1-S4 the average of the positive and the negative errors in cents for the participants who are musicians, for all the notes for the two activities, i.e. before (b) and after (a) using FONASKEIN for the training of their singing voices, along with the standard error of the mean.

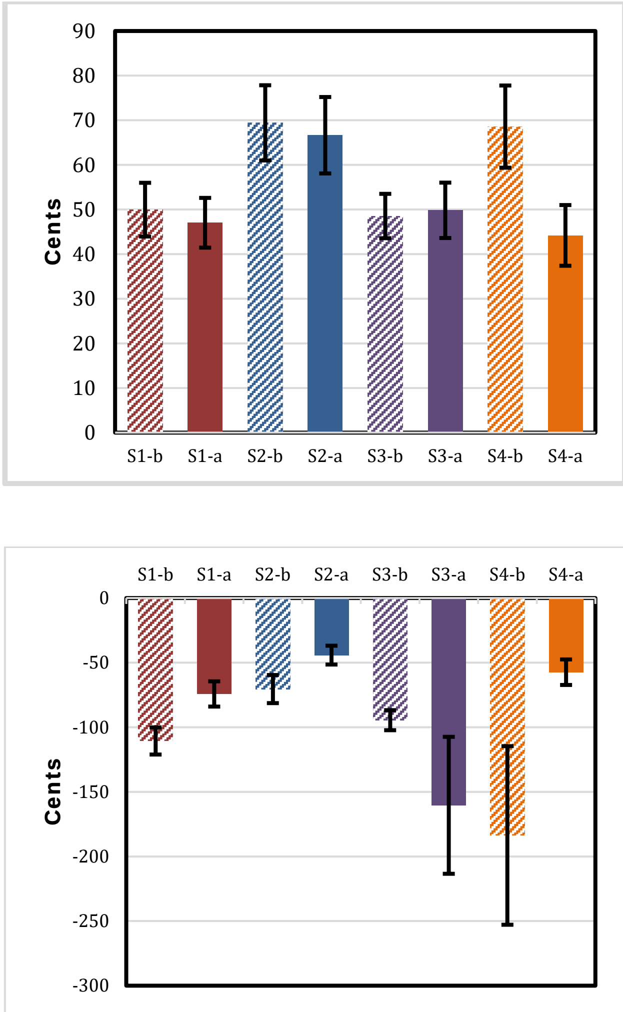
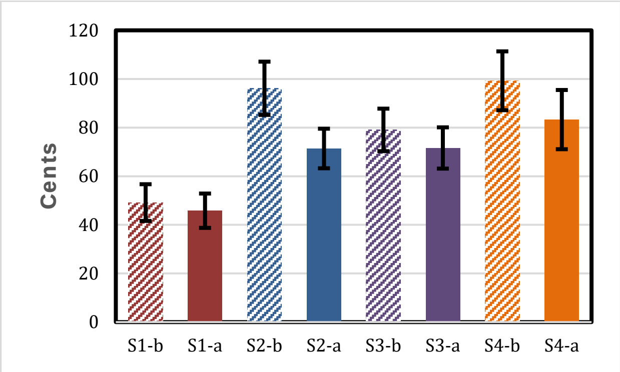


Figure 3. Average positive (above) and negative (bellow) errors in cents, for the participants who are musicians, for all the notes, before (b) and after (a) using FONASKEIN.

The number of negative errors was larger in almost all songs. We observed a positive effect on using FONASKEIN as the number of errors was reduced in all the cases of the songs S1-S4. The largest improvement was for S4 (126 cents for the negative errors and 24 cents for the positive errors). The smallest improvement was for S2 (3 cents for the negative errors and 27 cents for the positive errors).

Figure 4 presents for each one of the four songs S1-S4 the average of the positive and the negative errors in cents for the participants who are not musicians, for all the notes for the two activities, i.e. before (b) and after (a) using FONASKEIN for the training of their singing voices, along with the standard error of the mean. The number of negative errors was larger for all the songs. We observed a positive effect on using FONASKEIN as the number of errors was reduced in all the cases of the songs S1-S4, but much smaller compared to the relative for musicians. The largest improvement was for S2 (15 cents for the negative errors and 18 cents for the positive errors). The smallest improvement was for S1 (3 cents for the negative errors and 8 cents for the positive errors) and equally for S3 (7 cents for the negative errors and 4 cents for the positive errors).



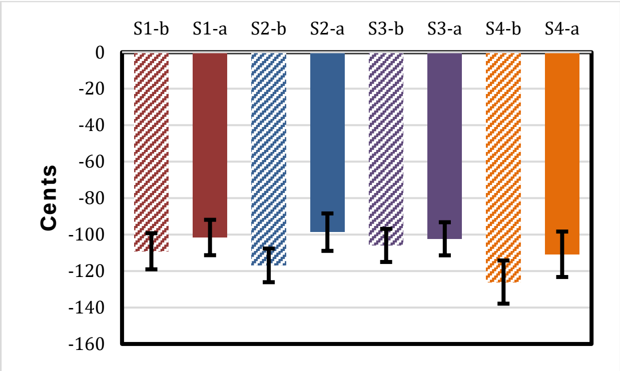


Figure 4. Average positive (above) and negative (bellow) errors in cents, for the participants who are not musicians, for all the notes, before (b) and after (a) using FONASKEIN.

6. CONCLUSIONS

We have presented the design and development of FONASKEIN, a novel modular interactive software application for the practice of singing in real-time and with visual feedback for both equal and non-equal tempered scales.

The evaluation results of FONASKEIN in a pilot experiment with eight participants and four songs in various musical scales showed its positive effect in practice of the singing voice in all cases.

In our future work we will study larger numbers of participants in various types of songs with non-equal tempered scales.

7. ACKNOWLEDGMENTS

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