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Seeing Sounds: The Effect of Computer-Based Visual Feedback on Intonation in Violin Education

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ABSTRACT

The fact that the violin is a fretless instrument brings along intonation problems both in its performance and in its education. The introduction of technology into educational environments day by day, has led to the need to try different methods besides the traditional methods for solving intonation problems. The aim of this study is to examine the effect of computer-based visual feedback on the student's intonation on the violin. For this purpose, an 8-week experimental process was carried out with 8 violin students studying in the 2nd, 3rd and 4th grades of the music teaching undergraduate program in the 2021-2022 academic year. In the quantitative dimension of the research, which was designed with mixed method design, a pretest – post-test single-group experimental design was used. The quantitative data were collected with the intonation evaluation form and the qualitative data were collected with diaries and a semi-structured interview form. The dependent samples t-test was used in the analysis of the quantitative data, and descriptive analysis technique was used in the analysis of the qualitative data. In the implementation process of the study, students were given visual feedback only with Cubase VariAudio software. At the end of the study, it was seen that computer-based visual feedback contributed positively to the intonation skills of the students. The students stated that the study made an abstract situation concrete, offered an opportunity to make self-evaluation, contributed positively to the motivation and limited class hours, and that they wanted to use it while practicing on their own.

Key words: Violin Education, Intonation, Visual Feedback, Computer-Based Training, Self-Assessment, Cubase VariAudio

INTRODUCTION

One of the biggest problems encountered both in the performance and in the training of the violin is to play it with the right intonation, that is, by hitting the target fret accurately. It is inevitable that intonation is an important problem in the training of the violin, which, due to its physical condition, has no marks or lines on its touch and can produce an estimated fifty-three notes in a tampered system (Flesch, 2000), although it has only four strings (Özcan, 2017). Intonation can theoretically be handled under two headings. They are: tampered and full intonation. In tampered intonation, the intervals in the octave are equal. In full intonation, on the other hand, the twelve intervals in the chromatic scale are not equal (Fayez, 2001). Different definitions or approaches have been developed by educators and researchers about what intonation is on the violin or how to develop it. Violin educator Galamian (2013), likened fingers to blind people and stated that correct intonation is based on the sense of touch with the guidance of the ear. According to Pardue and McPherson (2019), proprioceptive knowledge is needed to physically place a finger on the right fret. Suzuki, on the other hand, argues that intonation develops by singing, imitation and repetition. According to Suzuki, since the child knows the song, he/she will realize it when he/she presses the wrong finger (Sak Brody, 2020).

In violin education, a student is expected to have the ability to hear in order to provide the correct intonation, but besides this, support elements are employed to improve intonation. Traditional methods used to solve intonation problems can be sorted as verbal feedback and vocalization (Taş, 2020), playing with piano accompaniment (Yüksel & Mustul, 2015), making Solfeggio (Fayez, 2001), tape sticking on the touch or tactile marking (Knotts, 2018). In addition to these, it is known that music education approaches such as Orff, Kodaly, Suzuki and Dalcroze are used to improve intonation in violin education. Although many studies have concluded that these methods have a positive effect on intonation, they mostly contain auditory feedback. Tuners that offer visual feedback are still insufficient for feedback, ensuring very little for accurate feedback (Shen et al., 2022).

In addition to these methods that include auditory feedback, it is also necessary to provide rich learning environments that will activate different senses that will make the student more active in the learning process. From this point of view, employing visual elements seems like a good alternative to apply. Because today, students are constantly

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exposed to visual stimuli in every field and this situation causes their perceptions to be more open to visual stimuli (Borich, 2014). According to Demirel (2009), using visual tools in education is very important in terms of ensuring that learning is permanent. The more senses a teaching activity appeals to, the more permanent it is in learning, and accordingly, the longer it is to forget. The fact that the materials used in education are visually stimulating enables students to learn information more permanently (Bozpolat & Arslan, 2018). Based on the requirement that art education should be "open to creativity and not limited to narrow patterns", it is necessary to develop teaching methods in violin education, especially in order to get more efficiency from the instrument and the student, with wide boundaries and open to innovations by making use of different disciplines. In this context, different searches for teaching methods in violin education (possible contributions of adding new dimensions to playing/study methods from different fields to performance, etc.) come to the fore (Yağışan, 2008). As an extension of contemporary education, all possibilities of technology should be utilized, and audio and video recordings should be consulted for the analysis and evaluation of the student's performance, if necessary (Angı & Birer, 2016).

THEORETICAL FRAMEWORK AND RELATED STUDIES

Violin Training and Intonation

One dimension of music education is instrument training, and one dimension of the instrument training is violin training. Effective and productive development in the process of violin education can only be achieved at the end of a series of educational practices (Alpagut, 2004). In addition, for a qualified violin education process, the student should have musical memory, willingness, flexible muscles, appropriate hand structure, physical, mental and emotional health, concentration and perceptual qualities, as well as hearing ability (Akdeniz & Akdeniz, 2020). In addition to these qualifications in violin education, the student is expected to play it with the right intonation. Intonation, a musician's ability to produce the correct pitch of a note in a particular musical context, is a constant challenge for stringed instruments players (Chen et al., 2008). The famous violin virtuoso and instructor Louis Spohr (1843) stated that it is a great difficulty to achieve pure intonation with the complex mechanism of playing the violin, and that playing with the right intonation is an indispensable quality for this instrument. Spohr also added that the concept of perfect intonation should be understood as the equal temperament system (12 equal tones). Contrary to Spohr's view of using the equal temperament system in the violin, Repp (1997) stated that Fyk's (1995) intonation in the violin is a dynamic, content-oriented process rather than an invariable fixed sound system (Cited by Kalender, 2021). In the literature, it is generally accepted that western music uses a tampere sound system (12 equal tones), but it is also known that since the past, fretless instruments such as the violin have used the Pythagorean scale when they could not be played with an accompaniment of a keyboard instrument such as the piano. Recently, with the development of the technology and electronic musical instruments, tendencies to use sounds at every frequency that the human ear can distinguish have emerged in the West (Karaosmanoğlu, 2000). In addition to the student's hearing ability and the feedback given in violin education, the factors affecting intonation can be briefly listed as stance and hold (Günay & Uçan, 1980), keeping the fingers on the sound on the string (Büyükaksoy, 1997), bow pressure and double sounds (Tarkum, 2006), tempo (Duke et al., 1988) and playing with accompaniment (Zabanal, 2019). In addition, studies show that scale studies improve students' intonation (Uçar & Tanınmış, 2022).

Feedback in Violin Training

Feedback is the information given to define the difference between the student's performance and the targeted performance in the education process and to increase the student's performance to the desired level (Özalp & Kaymakçı, 2022). Feedback can also be defined as the perceptual response that the individual receives from various sensory organs and biomotor and psychomotor skills. It occurs when an action or behavior is reacted or in the learning process and directly affects the learning skills of the individual (Çetinkaya, 2018). Feedback is at the center of learning of an instrument and provides vital information to the learner about his/her performance. While feedback can be in the form of listening to the student's own performance instantly, recording and listening to it later, or receiving feedback from other students or experts, music technologies can also play an important role in solving the problem of effective feedback (Yee-King et al., 2019). Based on the fact that sounds cannot be seen in music education, it can be said that auditory feedback is used more. With the increasing number of technological tools that provide real time visual feedback of sound, their impact on current and possible pedagogical applications in music education is also discussed (Lã & Fiuza, 2022). Technological developments, especially in the last 50 years, the widespread use of computers and mobile devices provide music educators and students with unrealized opportunities in terms of visualizing and evaluating sounds both in real time and offline (Acquilino & Scavone 2022). In order to take advantage of the opportunities offered by technology, both students and educators need to strengthen their digital literacy Omur and Sonsel (2021). Scott (2013) also emphasizes that although students have a high level of digital literacy and show a willingness to adopt new technologies, there is a disconnect between the use of technology in personal contexts and the music classroom.

When studies on intonation on violin or stringed instruments in the literature are examined, it can be seen that researchers abroad show more interest in the subject. Studies examining the effects of visual and auditory feedback (Blanco et al., 2021; Pardue & Mcpherson, 2019), the effectiveness of digital visual feedback (Yin et al., 2005), the effect of tactile marking method (Knotts, 2018), the effect of vocalization, verbal feedback and piano accompaniment on intonation on string instruments (Taş, 2020), intonation

problems encountered in violin education and their solutions (Angı & Birer, 2013), and the creation of a curriculum for the development of intonation (Kalender & Akgül Barış, 2022) have taken their place in the literature.

Purpose and Importance of the Study

According to Swift (2003), what is expected from students in instrument education is to play it with the correct intonation without the teacher's warning, but this is often not possible. Especially at the beginning stage. For this reason, students constantly need feedback. In violin education, the use of methods that can provide technology-supported visual feedback as well as auditory and traditional feedback can create a rich and effective learning process. In addition, considering that students usually meet with their teacher once a week, technology-based visual feedback methods can also offer students great opportunities for self-evaluation. In the literature, it is seen that the studies on intonation are mostly auditory, the intonation is handled theoretically, and there are few experimental studies (Kalender, 2021). Contrary to the traditional methods and researches applied to the solution of intonation in violin education, this study is important and separates from other studies because it is an experimental and new approach that includes visual elements, supports computer-based quantitative data with qualitative data, and tries to develop an experimental and new approach in which students can evaluate themselves.

In this context, the aim of the study is to examine the effect of computer-based visual feedback on the intonation skills of violin students. For this purpose, the problem statement of the study is formed as "What is the effect of computer-based visual feedback on students' intonation skills in violin education?". The sub-problems of the research are presented below.

1. Is there a significant difference between the pretest – post-test (1st lesson-8th lesson) intonation scores of students receiving violin education with computer-based visual feedback?
2. Is there a significant difference between the 1st lesson pretest – post-test intonation scores of the students receiving violin education with computer-based visual feedback?
3. Is there a significant difference between the 8st lesson pretest – post-test intonation scores of the students receiving violin education with computer-based visual feedback?
4. What are the students' views on the computer-based visual feedback application?

METHOD

Model of the Research

This study is a mixed method research. Mixed method research is defined as a research type in which the researcher combines quantitative and qualitative research techniques, methods, approaches, concepts or the language in a single study (Johnson & Onwuegbuzie, 2004). The usage of the combination of quantitative and qualitative techniques in mixed method allows us to better understand the events compared to using a single technique (Creswell, & Clark, 2015). The reason for choosing the mixed method in this study is to try to better understand the research problem by using quantitative and qualitative techniques that will lead us to multiple data with different strategies. In the study, the explanatory design, which is one of the mixed method designs, was used. First, quantitative data were collected, and then qualitative data were collected in order to interpret, deepen and enrich the data (Creswell & Clark, 2015). In the quantitative dimension of the research, the pretest – post-test single-group quasi-experimental design was used. In this design, the significance of the difference between the pretest and post-test values of a single group (G) is tested (Büyüköztürk et al., 2010). In the qualitative part of the research, data were collected through student diaries and semi-structured interviews. The method followed in the research and the experimental design are shown in Figure 1.

Study Group

Purposive sampling method was used in determining the study group in accordance with the nature of the research (Büyüköztürk et al., 2010). The study group of the research consists of 8 students, four female and four male, receiving violin education at the 2nd, 3rd and 4th grades of undergraduate level, Necmettin Erbakan University, Department of Music Education. Undergraduate 1st grade students were not included in the study by taking expert opinion, as they have just started violin education and the risk of not being able to play the repertoire to be used in the study.

Data Collection Tools

In the study, the quantitative data were collected with the intonation evaluation form and the qualitative data were collected with diaries and an interview form.

Intonation evaluation form

In order to detect intonation errors in the study, the "Intonation Evaluation Form" was created by the researcher by taking expert opinions. In this form, there are 84 notes from the "A major scale and etude" and "C minor scale and etude" repertoire, whose visuals are given in the application process section of the study. The intonation error was calculated as the cent difference between the target pitch and the pitch played. Tampered sound system (equal temperament) was used to detect the intonation error. In this system, a semitone is 100 cents and an octave is 1200 cents. The Cubase Variaudio software we used to collect the data in the study shows us the pitch in cents both graphically and numerically. In the literature, there are studies that reach different conclusions about how many cents the human ear can detect. According to Loeffler's (2006) study, the human ear can distinguish a difference of five or six cents. The scale in this study was created in the form of 0-5 cent intervals in 7-point Likert type based on Loefler's research results. Then,

the expert opinion of two faculty members, one of which is a violin educator and the other a hearing educator, was consulted in terms of content and construct validity. These two field experts listened to the 5-cent pitch differences prepared as midi on the computer, and it was concluded that it would be appropriate to use the scale by designing it in 5-cent differences. In the final form of the form, as seen in Table 1, the distance of 0-5 cents from the correct pitch represents the "Very good" grade. It was rated that 6-10 cents distance from the right pitch is "Good", 11-15 cents distance is "Slightly good" 16-20 cents distance is "Moderate", 21-25 cents distance is "Slightly bad", 26-30 cents distance is "Bad" and 31 or more cents distance is "Very bad".

The scores of the students regarding the distance of the sounds they pressed to the correct pitch were first recorded in the excel file, then cleared from the pluses and minuses, and finally transferred to the 7-point Likert-type observation form. The Cronbach's Alpha Reliability Coefficient of the Intonation Evaluation Form, which includes 84 items, is 0.782. Since the Cronbach's Alpha coefficient of the Form was above 0.70, it was accepted to be reliable (Sönmez & Alacapınar, 2018).

Diaries

Students were asked to write diaries reflecting their feelings and thoughts about the study. Yıldırım and Şimşek (2008) stated that the participants' keeping a diary about the application during the research process may be helpful in reaching individual observations, reactions to emotions, comments and explanations.

Interview form

After the experimental study, students' opinions were sought in order to add depth to the study, to determine their experiences and feelings about the application, and to give detailed information about their views on the model. In the form prepared by the researcher, there are open-ended questions aiming to determine the current situation of the students regarding intonation while playing the violin, their first impressions of the model, the advantages of the application and their suggestions for the application. During the creation of the form, the interview forms were finalized by using the opinions of two music educators, one of whom is a violin instrument expert, and a Turkish teacher working at Necmettin Erbakan University. The interview form was applied after the post-test measurement.

Data Collection

The research data were collected in an 8-week period in the 2021-2022 academic year. The data in the quantitative dimension of the study were collected with the intonation evaluation form, and the data in the qualitative dimension were collected with the diaries and the interview form. In studies using the pretest – post-test single-group quasi-experimental design, it is seen that quantitative data are generally collected at two different times, before the application (pretest) and at the end of the application (post-test). In this study, this situation was expanded a little more and data were collected at four different times: at the beginning of the first lesson, at the end of the first lesson, at the beginning of the eighth lesson and at the end of the eighth lesson. This was done to detect the curiosity of the effect of the application performed in the study on intonation in a short time. A total of 2,688 notes were recorded, 84 notes per student in each sound recording. The recordings were made in the study room of the researcher at the university. A pilot study was conducted before the implementation. A Rode NT-1000 Condenser microphone was used first during the recording in the pilot study. It was observed that the microphone picks up external sounds and reduces reliability. For this reason, an AKG C411 Condenser instrument microphone was used instead of the Condenser microphone. Since this microphone is attached to the violin, it is observed that external sounds are prevented from recording and a better quality and clear sound is obtained. Technical materials used in the study are a desktop computer, 32 inch LCD screen, RME Babyface Pro sound card, Cubase 8 Pro-Variaudio, AKG C411 Condenser instrument microphone. In the qualitative phase of the study, a total of 16 diaries were collected from the students. After the application process, a face-to-face semi-structured interview was conducted with the students.

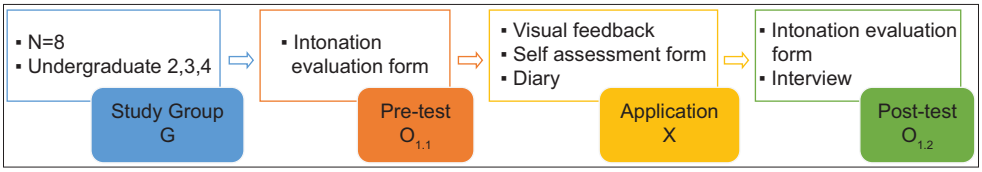

Figure 1. Research design

Table 1. Intonation evaluation form

No	Gain	Very good (0-5)	Good (6-10)	Slightly good (11-15)	Moderate (16-20)	Slightly bad (21-25)	Bad (26-30)	Very bad (31-…)
		7	6	5	4	3	2	1
1	Presses La 2 pitch correctly							
2	Presses Si 2 pitch correctly							
3	"	"	"	"	"	"	"	"

These interviews lasted approximately 25 minutes with each student.

Data Analysis

In the quantitative phase of the study, the data obtained from the Intonation Evaluation Form were analyzed with the dependent samples t-test, recommended in the literature for the single-group pretest – post-test experimental design (Büyüköztük, 2018). Before this analysis, a normality test was performed to see whether the difference scores of the data set were suitable for the test. The coefficient of skewness was calculated as -.339 and the coefficient of kurtosis was calculated as -.308. As a result of the normal distribution analysis, when the requirement that the kurtosis and skewness be between ±1 was examined, it was determined that these values fit the normal distribution according to the variables (George & Mallery, 2010). In addition, as seen in Table 2, as a result of the values obtained from the Shapiro-Wilks test, which is preferred in cases where the number of samples is less than 50, it is seen that the data set is normally distributed. For this reason, the t-test, one of the parametric test techniques, was used for the analysis of the quantitative data (Büyüköztürk, 2018).

Descriptive analysis technique was used in the analysis of the qualitative data collected in the research. Data obtained in this technique are summarized and interpreted according to predetermined themes, and direct quotations are frequently used in order to reflect the views of the interviewed and observed individuals in a striking way (Yıldırım & Şimşek, 2008, p. 224). According to Creswell and Clark (2015), qualitative data analysis includes coding the data, dividing the text into small units, assigning labels to each unit, and grouping the codes under themes. In the study, similar data and concepts were brought together under previously created categories and coded. In order to ensure reliability in the coding process, cross-coding was done with a field expert. Consistency (Agreement + Disagreement) reliability formula used by Miles and Hubermann (1994) was used to examine the consistency between the coders and the consistency rate was found to be 0.96. According to Miles and Huberman (1994), it is sufficient for the consistence ratio to be 0.90. The resulting codes were presented as sub-themes and themes, and the data were interpreted within the framework of these findings. In addition, direct quotations from student opinions and diaries were frequently included to support the findings in the study.

Implementation Phase

This study covers an 8-week application process carried out individually with each student in the 2021-2022 academic year. In the study, visual feedback was provided to identify and solve students' intonation problems using Cubase VariAudio, a computer-based software. Scales and etudes presented in Figure 2 were used as repertoire in the application.

As seen in Figure 2, the repertoire used in the study consists of A major scale and etude and C minor scale and etude in the first position. Empty strings and some voices were excluded from the evaluation, and a total of 84 sounds were included in the scales and etudes created for the research by taking the opinion of a violin and hearing educator field expert. These two tones were chosen because they contain all the chromatic sounds in the first position on the violin keyboard.

Before the application, students were informed about the use of the Cubase Variaudio software. Afterwards, the repertoire was played by the participants. While the students were playing the repertoire, instant audio recordings were taken. Afterwards, the recording was turned on and the intonation states seen in Figure 3 were visually reflected on the screen with graphics and numbers. In other words, the participants were not given any feedback by the educator, and they were asked to analyse and interpret their own intonation problems with computer-based graphics and numbers. In addition, the students stated the pitch deviations and what kind of strategy should be applied in order to reach the target pitch on the "Intonation Self-Evaluation Form" in writing. This form is: "…. my pitch is … cents higher/lower than it should be.… I have to press my sound higher/lower". Then the students were asked to play the repertoire again and the results were shown to the students again. This process, which was reserved for twenty minutes, continued for eight weeks with the same repertoire. Students were asked not to make vibrato during the performance because vibrato prevented us from reaching sharp and clear results about the pitch (Yang et al., 2016). During the application, scales were performed at 66 bpm and etudes were performed at 80 bpm.

Table 2. Normality test results

Statistics	df	p
0.963	8	0.840

FINDINGS

Findings Regarding the First Research Question

Findings regarding the question "Is there a significant difference between the pretest – post-test (1st lesson-8th lesson) intonation scores of students receiving violin education with computer-based visual feedback? which is the first research question of the study are given in Table 3.

When Table 3 is examined, it was determined that the difference between the pretest – post-test scores of the students was statistically significant at the 95% confidence level ($t=-5.932$, $p<.05$). The post-test scores of the students were higher than their pretest scores. While the average of the students' pre-application (first lesson) intonation level scores was at the "moderate" level with 4.21, the average of the scores after the application (eighth lesson) increased to the "Slightly good" level with 5.02. This finding shows that computer-based visual feedback is effective in increasing students' intonation levels.

Findings Regarding the Second Research Question

Findings regarding the question "Is there a significant difference between the 1st lesson pretest – post-test intonation

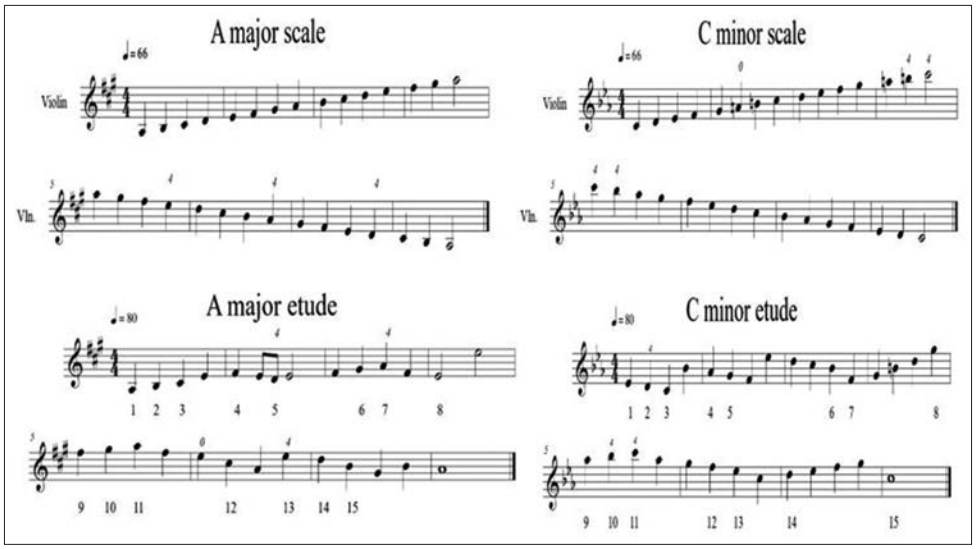

Figure 2. Scales and etudes used in the study

Figure 3. Photos of the implementation process

scores of the students receiving violin education with computer-based visual feedback?" which is the second research question of the study are given in Table 4.

When Table 4 is examined, it was determined that the difference between the students' first lesson pretest – post-test scores was not statistically significant at the 95% confidence level (t=-0.456, *p*>.05). While the average of the scores of the students' intonation levels before the application in the first lesson was at the "moderate" level with 4.21, the average of the scores after the application in the same lesson was at the "moderate" level with 4.28. Although there was an increase in the arithmetic mean scores, it did not make a significant difference both statistically and according to the intonation evaluation form. This finding can be interpreted as the application in the first lesson was not effective in increasing students' intonation levels.

Findings Regarding the Third Research Question

Findings regarding the question "Is there a significant difference between the 8st lesson pretest – post-test intonation scores of the students receiving violin education with computer-based visual feedback?" which is the third research question of the study are given in Table 5.

When Table 5 is examined, it was determined that the difference between the eighth lesson pretest – post-test scores of the students was statistically significant at the 95% confidence level (t=-8.789, *p*<.05). The post-test scores of the students were higher than their pretest scores. While the average of the students' pre-application scores in the eighth

Table 3. Distribution of students' pretest – post-test (1st lesson-8th lesson) scores and dependent samples t-test analysis

	n	*M*	*Ss*	*t*	*df*	*p*
Pretest	8	4.21	0.48	-5.932	7	0.001
Post-test	8	5.02	0.41			

*p<.05

Table 4. Distribution of students' 1st lesson pretest – post-test scores and dependent samples t-test analysis

	n	*M*	*Ss*	*t*	*df*	*p*
Pretest	8	4.21	0.48	-0.456	7	0.662
Post-test	8	4.28	0.43			

*p<.05

Table 5. Distribution of students' 8th lesson pretest – post-test scores and dependent samples t-test analysis

	n	*M*	*Ss*	*t*	*df*	*p*
Pretest	8	4.35	0.43	-8.789	7	0.000
Post-test	8	5.02	0.41			

*p<.05\

lesson was at "moderate" level with 4.35, the average of the post-application scores in the same course increased to "Slightly good" with a score of 5.02. This finding shows that the practice in the eighth lesson is effective in increasing the students' intonation levels. The finding that there was no significant difference between the pretest and post-test results in the first lesson, but there was a significant difference between the pretest and post-test results in the eighth lesson can be interpreted as the students' adaptation to the application for eight weeks.

Findings Regarding the Fourth Research Question

Findings regarding the question "What are the students' views on the computer-based visual feedback application?" which is the fourth sub-problem of the study are, given in Table 6.

The students stated that while they were working on their own, they controlled their intonation by making solfeggio, using a tuner, taking reference from the piano and empty strings.

There are digital tuners now. I use them for intonation, but if I had such an opportunity, I would never stay away from the computer and study. [S3]

I control it with the piano, first I press the keys and then I play it with my violin, but it's a bit tiring. If you ask me whether to prefer the piano or this application, of course, I would prefer this application. [S5]

We refer to the empty string at the intonation point, so we do the crosscheck with the empty string. In this study, it is no longer needed. [S6]

There aren't many tools to help me evaluate myself. I can't get such a clear and sharp result with instruments like tuners. [S7]

Students expressed their first impressions of the application as surprising and scientific.

I was very surprised. Because I always thought I pressed right up to now. I didn't know I pressed that high. [S2]

Table 6. Students' views on the implementation

Theme	Sub-theme
Tools for checking students' intonation	Making Solfeggio
	Using a tuner
	Referencing from the piano
	Getting reference from empty strings
First impression	Surprising
	Scientific
Advantages	Positive effect on intonation
	Make an abstract situation concrete
	Provide an opportunity for self-assessment
	Positive effect on motivation
	Positive effect on limited class hours
	Trustworthy
	Practical
Suggestions	Students use when working on their own
	Teacher use in class

Dear Diary. Thanks to the experiment applied on me in our lesson today, I saw how the art we did was actually parallel to science and technology. I suspected that I had mispressed some sounds on the E and G strings, and this study proved it with graphics and numbers. I was very surprised, it was as if my sounds had been x-rayed. [S8]

The students listed the advantages of the application with computer-based visual feedback as; its positive effect on the intonation, making an abstract situation concrete, providing an opportunity for self-evaluation, affecting the motivation positively, contributing to the limited class hours, and being reliable and useful.

There are no disadvantages of this work, on the contrary, it tells me how to play. [S3]

First of all, I see that our application was not wasted and was effective. Even if we don't consider it digitally, the difference is clear when we listen to two audio recordings. I think, even a non-musician person can tell the difference between my first and last play. Of course, being visual provides more robust data. Everything was abstract before, it just has become concrete. [S1]

Seeing how low or how high I pressed rationally on numbers and graphs gave me self-assessment. [S6]

Before I saw the sounds, I used to decide which finger to press forward and not back, but as the time passed, I started to press by examining the self-assessment form at the point of pressing which one forward and which one back. [S1]

Before this study, I used to find the places of the sounds as I memorized, but now I will try to play every sound to play by thinking before I press it. [S3]

When I first saw the visual, I was a little depressed, but I am very happy to see that it has improved over time. [S1]

I think it is very useful. I became aware of my sounds that were wrong, it was a different feeling for me. I realised that it carried me forward from the point where I started. Therefore, my desire to work harder and correct my sounds increased. [S4]

Seeing my mistakes made me more motivated to work. I checked to see where I did wrong. Also, I am happy when I press the sound fully. [S5]

Our lesson is one hour a week and that time is limited. So this method of self-assessment offers great advantages. [S6]

I think the program is reliable. I pressed high in my first practice, and it showed high. Then I deliberately pressed low and it showed low. As a result, I realized that it is reliable. [S3]

I don't know very clearly whether I press high or low, but this application sees it. It will be very beneficial for me if I use this device while working by myself. For example, I pressed the following sound too high; I would see it as if I had pressed +37 cents, and tried to correct it. I would try to bring all my sounds at least up to ±10 cents, it's a very useful application. [S2]

As suggestions regarding the application, students stated that it can be a good alternative for violin students to check

their intonation status while they are studying on their own, and that teachers can also use it in lessons.

> *Since our instrument is fretless, it is very risky in terms of intonation, we have to press it in millimetres. If I had the opportunity at home, I would definitely try this method to press clearer sounds.* [S1]
>
> *If I work with this application at home by myself regularly and by checking, my intonation will improve.* [S2]
>
> *If I had the opportunity at home, I would do intonation exercises before every practice. Then I would compare my sounds to see if I had improved over time." I think all students who have the opportunity should get it. In addition, teachers can use this method to see and show the progress of students too. It can also be used for position transitions.* [S8]

DISCUSSION

In this study which examined the effect of computer-based visual feedback on students' intonation skills in violin education, the data were collected both quantitatively and qualitatively. When the quantitative findings regarding the first sub-problem of the study were examined, it was determined that there was a significant difference in favor of the post-test in the pretest (1st lesson) and post-test (8th lesson) intonation skills after the application, and that the method contributed positively to the students› intonation skills. In the study, the short-term effect of the application was also questioned. For this reason, data were collected at the beginning and end of the first lesson and at the beginning and end of the eighth lesson. When the findings regarding the pretest and post-test in the first lesson were examined, no significant difference was found. In the eighth lesson, on the other hand, a significant difference was found in the opposite direction. This difference can be interpreted as that the students had a problem of adaptation to the application at the beginning, and that they overcame this problem after eight weeks.

When the studies on the effect of visual feedback on intonation in violin education were examined, it was seen that the studies reached positive findings. Because, according to Wang et al. (2012), obtaining visual feedback is important for violin students and it affects the learning process positively. Yin et al. (2005) reached the finding that visual feedback has a positive effect on violin students' performance in their study. Researchers have designed an Interactive Digital Violin Teacher application that allows students to receive feedback in the cases when there are no teachers available. It is stated that the application, which presents the violin sound with different visualization modalities such as video, 2D keyboard animation or 3D avatar animation, helps students to practice on their own and positive results are obtained. Blanco et al. (2021) examined the pitch matching skills in the violin and human voice of the study group, who had no previous musical education, in three ways, namely visual, auditory and without any feedback, and an improvement was observed in the skills of the participants who received feedback. In addition, students who received visual feedback both improved and preserved their skills at the point of pitch matching. Pardue and Mcpherson (2019) examined three simultaneous feedback methods for real-time intonation detection in a study they conducted with violin students. These are the feedback methods of auditory, visual and the combination of both. As a result of the study, it was concluded that learning using auditory and visual feedback takes time, and feedback methods have a positive effect on intonation and have a potential for self-evaluation.

Apart from violin education, which has found that visual feedback has a positive effect on students' intonation skills, studies from different fields of music education have also taken their place in the literature. Jeanneteau et al. (2022) concluded in their study that visual feedback has a positive effect on intonation in the training of singing. Similarly, Kruijshaar (2020) reached positive results as a result of his study in which he examined the effect of visual feedback on student performance in music lessons. Paney and Kay (2015) examined the effect of computer-assisted simultaneous visual feedback on students' pitch matching skills and concluded that students experience musical development in a short time even when they have limited class hours. Lã and Fiuza (2022) suggest using visual feedback as an important approach in current and future voice training courses. Eldridge et al. (2010) studied the effect of visual feedback on pitch recognition and reinforcement skills in piano education, and it was concluded that the group given auditory feedback had less pitch recognition skills than the group given visual feedback. According to the researchers, it is reported that sensory excess in instrument training increases the robustness of learning and that visual feedback should be used in instrument training as well as auditory feedback. In the literature, there are studies showing that visual feedback has a positive effect on the development of motor skills in different areas other than music education (Martínez et al., 2016; Derbali et al., 2019).

According to the findings in the qualitative dimension of the study, the students stated that they were able to self-evaluate with this method. Supporting this finding, according to Bayrak and Yurdugül (2016), technology can provide support to self-evaluation and learning processes of individuals. According to the findings of the study, the students stated that they took reference from empty strings. Supporting this finding, according to Angı and Birer (2013), in addition to good tuning, it is necessary for students to compare sounds from time to time using empty strings and thus try to understand whether they are in tone or not, for the development of intonation. According to the findings, the students stated that they tuned using the piano, but it was difficult and tiring. According to Klickstein (2009), there are options such as controlling the sounds played with the help of a correctly tuned piano in order to improve the intonation skills of violinists (As cited by Tehli, 2020), but there are two points to be considered here. First, with this method, the student's hearing ability is still at the forefront, so if the student's hearing ability is not developed, they will not be able to hear the pitch difference. Another point is whether the piano's tuning is correct or not. In a study conducted by Umuzdaş and Baş (2020) with fine arts high schools, some participants stated that the pianos in their schools were out of tune. Taking a

piano out of tune as a reference for intonation can reinforce a mistake and cause different problems. This is also a point to be noted.

Students stated that the VariAudio software used in the study gave reliable results. In support of this finding, Cankayan (2013) examined the reliability of various sound analysis programs, including Cubase VariAudio software, and concluded that this application measures pitch with a success rate of 96% in a single voice and a single instrument. According to the findings of the study, the students stated that they could see their development visually with this application, and their motivation increased with the visual concretization of an auditory situation, which they described as abstract. According to Doğru and Aydın (2018), using technology in lessons to make abstract situations concrete with visuals provides convenience in learning. In support of these findings, according to Acquilino and Scavoney (2022), the development of low-cost applications that provide visualization and feedback in instrument education provides opportunities for students to collect data about the development at their own level, analyze the data, monitor their progress and determine the working method, while improving stress management and will increase the motivation to work. According to the research findings, the students stated that they could not receive enough teacher feedback due to the limited class hours, which negatively affected their development, but they thought that such an application would contribute significantly to their development in terms of providing feedback while practicing on their own. Supporting these findings, Yin et al. (2007) stated that rapid feedback is of vital importance in violin education, but most students only meet with their teacher once a week, so systems in which students can control themselves should be developed.

CONCLUSION

In this study, the effect of computer-based visual feedback on students' intonation skills in violin education was examined. At the end of the study, it was seen that computer-based visual feedback contributed positively to the intonation skills of the students. The students stated that the study made an abstract situation concrete, offered an opportunity to make self-evaluation, contributed positively to the motivation and limited class hours, and that they wanted to use it while practicing on their own. This study is limited to 8 students studying violin at the undergraduate level of 2nd, 3rd and 4th grades in the field of Music Education at Necmettin Erbakan University in the 2021-2022 academic year, with an 8-week experimental period, with scales and etudes created for the study, using the Cubase 8 Pro for sound recording and the VariAudio software and equal tempering system for analysis. As a result of the findings obtained from the study, the following recommendations are presented.

1. Computer-based visual feedback method can be used to evaluate intonation problems in both violin education and stringed instruments education.
2. In order to determine the intonation levels of students, software that can record, analyze simultaneously or not simultaneously, provide reliable results, is simple, inexpensive, useful and suitable software for mobile devices can be developed.
3. Future studies may examine the difference between digital and jury measurements.
4. Studios can be established at universities and offered to students to collect their own intonation data.
5. The scope of the research can be expanded by working with the students of vocational and aspiring music education institutions.
6. More technology-supported experimental studies can be conducted to increase intonation skills and the results can be discussed.
7. Studies can be conducted to improve the digital literacy of students and educators so that they can adapt to developing technologies in music education.

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