ImproScales: a self-tutoring web system for using scales in improvisations

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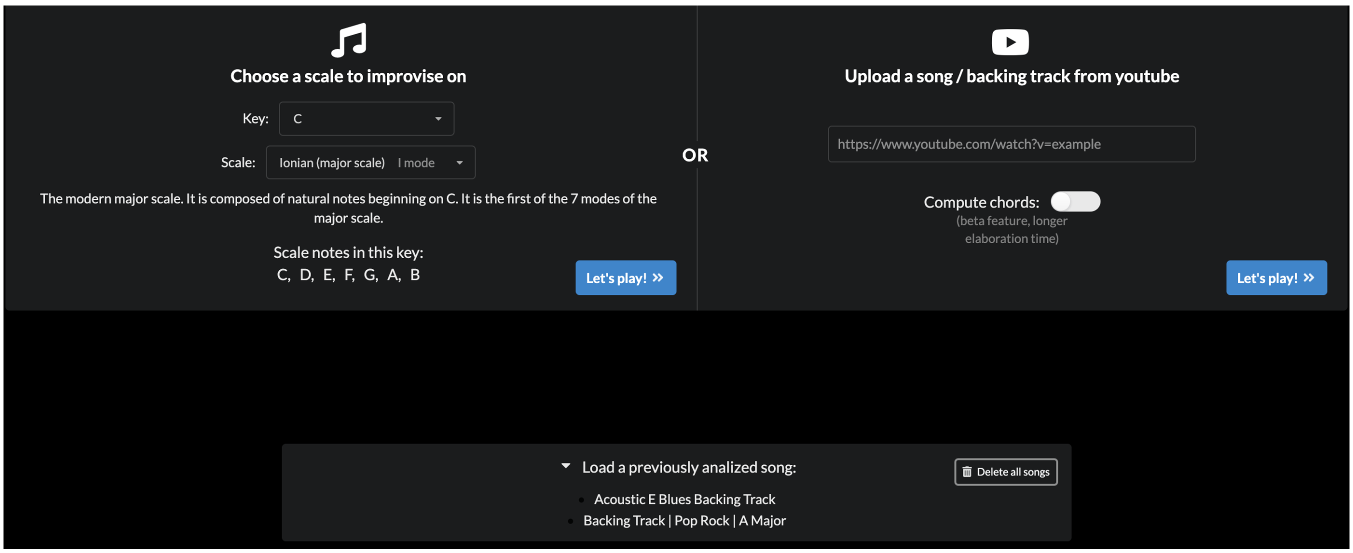

Figure 1: The landing page of the web app, where it is possible to choose between the two use cases implemented.

ABSTRACT

This paper describes ImproScales, a Web Audio application devised to support musicians in the process of learning to use scales during improvisation. The web application detects in real-time the notes played by an individual instrument and assesses whether they belong to the scale, and as a result provides statistics about the number of errors made. Two use cases were implemented following a design process conducted with interviews with musicians: scale practicing with the sole instrument and scale practicing with accompanying music retrieved from YouTube. The first use case is primarily intended for those musicians who do not know well the musical scales and want to learn them properly, or for those who want to practice without a backing track, while the second is meant for people who already know the scales and want to improvise over a song or instrumental music. We report the results of a user study conducted with twelve intermediate musicians. Overall, results show that the application was deemed effectively capable of enhancing musicians' improvisation skills. A critical reflection on the results achieved is reported along with the analysis of weaknesses and limits of the web application, as well as some proposals for future developments are provided.

CCS CONCEPTS

• **Applied computing** → **Sound and music computing**; *Interactive learning environments*; • **Human-centered computing** → Sound-based input / output.

KEYWORDS

Music tutoring systems, improvisation, Web Audio, Internet of Musical Things

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1 INTRODUCTION

Today, various kinds of technologies are being used by musicians in their regular practice to facilitate and enhance Western music learning, in terms of both practice and theory [11]. The attention of researchers has been devoted to the development of music tutoring systems based on musical instruments [2, 12, 17], tools [3], software [6, 20, 21], and web services [1, 8, 13]. On the other hand, various services exist today that support musicians in the process of learning specific songs, chords or melodies (noticeable examples are app such as Yousician[1], Solfeg.io[2], or Chordify[3]).

A topic which has received comparatively little attention in this space is that of systems specifically built for music improvisation, notwithstanding improvisation is an essential competence of musicians in several genres (e.g., jazz, blues, rock, metal, etc.) [4, 14]. Existing examples include augmented reality applications for improvisation learning on the piano [10, 23]. Nevertheless, most of music technology works concerning improvisation have focused on automatic generative music, in both interactive and non-interactive fashion (see e.g., [18, 19]).

In this paper we present a Web Audio application devised to allow musicians to enhance their improvisation skills, by providing them feedback and statistics on what they play. Specifically, we exclusively focused on the use of scales [22], not on polyphonic improvisations. The design process started from an investigation of the needs of musicians in relation to improvisation and supporting technologies. This activity yielded the musicians' request for a self-tutoring system supporting their improvement on the use of scales during improvisations. The system was intended for an interactive use, where the musician could receive real-time feedback as s/he plays: the application detects in real-time the notes played by an individual instrument and assess whether they belong to the scale, and as a result provides statistics about the number of errors made. Such interactivity can be made possible by real-time music information retrieval techniques, which enable to extract from relevant quantities from the acoustic signal generated by the musician [5].

A noticeable feature of the web application is that not only supports improvisation learning when a musician plays the instrument alone, but also it allows musicians to improvise over music retrieved from YouTube. The latter case falls in the remits of the Internet of Musical Things paradigm [25]. We opted for a web application in place of a standalone software of conventional app for mobiles because of the portability benefit (developing a single web application with a responsive interface is far less time demanding than building a native application for every mobile and desktop environment) and to avoid any installation procedure.

To determine how well a system like ImproScales addresses musicians' needs, we conducted a user study with twelve intermediate musicians. The objective of the evaluation was to assess two key issues: user experience and learning efficacy. Specifically, we addressed two research questions:

(1) RQ1: Does a system like ImproScales provide a high user experience, adequate to support musicians' learning of the use of scales for improvisation?
(2) RQ2: To what extent can a system like ImproScales promote the learning of the use of scales for improvisation?

[1]https://yousician.com/
[2]https://solfeg.io/
[3]https://chordify.net/

The developed web application[4] the source code[5] and a video[6] showing its usage are freely accessible online.

2 DESIGN

We conducted semi-structured interviews with four electric guitar players to investigating the needs and habits of the target users. As a result, we identified two main use cases for which an app could be designed to support monophonic improvisation over scales (see Figure 1):

Scale practicing with the sole instrument: through the app the user can:

(1) choose a key and a scale to learn or improvise on;
(2) visualize real-time feedbacks on the notes played (whether they are in or out of scale);
(3) check the overall statistics at the end of the performance.

Scale practicing with accompanying music: through the app the user can:

(1) download from YouTube a song on which to improvise;
(2) choose whether to improvise it on the key and scale suggested by the system or on a scale selected by the user;
(3) choose to toggle the chords visualization;
(4) improvise on the song and view the feedback in real time;
(5) check the statistics at the end of the song.

The first use case is primarily intended for those musicians who do not know well the musical scales and want to learn them properly, or for those who want to practice without a backing track, while the second is meant for people who already know the scales and want to improvise over a song or instrumental music. Thus the app targets musicians with all level of expertise, from beginners to experts.

The selected scales were, for all 12 keys, the seven modes of the major scale (ionian, dorian, phrygian, lydian mixolydian, aeolian, locrian) and the minor and major pentatonic. Relevant statistics deemed useful for both use cases were: 1) the number of correct notes played and errors made during a single practicing session (correct notes were those belonging to the scale); 2) the global statistics for number of played notes, correct notes and errors (i.e., encompassing all practicing sessions).

3 IMPLEMENTATION

3.1 System setup and components

The web application is conceived to be used with specific hardware for optimal functioning: a microphone or an instrument directly plugged to the soundcard (with sample rate at least 44.1 KHz), a PC with monitor, and a pair of headphones. This setup is particularly relevant for the second use case, where the sound of the musical instrument is superimposed to that of a backing track. Figure 2 shows the setup used by a participant during the evaluation sessions.

The application is built on core web technologies: HTML5 for creating the content of pages, CSS for styling and Javascript supported by jQuery for enabling the interaction of the web pages. By implementing platform-independent techniques, the web app was made

[4]https://Improscales.herokuapp.com
[5]https://github.com/thomasborgogno/impro-scales
[6]https://youtu.be/lbZDL6ffvcs

Figure 2: A picture of the setup used by a participant during the evaluation sessions.

cross-platform, fulfilling the requirement to run on most of available devices by the principle of ubiquitous music computing [16]. The audio engine relies on Web Audio libraries. In particular, we used Essentia.js [9] for the real-time detection of the instruments notes and the analysis of the downloaded audio file from YouTube. Other libraries utilized include wavesurfer.js, the youtube audio stream, FFmpeg, and Fomantic-UI.

With the adoption of both HTML5 and the W3C Web Audio API specifications, modern web browsers are capable of audio processing, synthesis, and analysis without any third-party dependencies on proprietary software. Essentia.js extends these audio capabilities even more, providing a wide range of low-level and high-level audio features in a user-friendly API. By having these packages of functionalities available, it becomes simpler to program web applications that perform processing on the client, as in our case, which may be advantageous for many reasons: moving the audio processing code from the server to the client decreases the overhead on the web server, providing better scalability and deployment; it can provide faster response times, as long as the web client has computational resources for the required processing; it can make the application more interactive.

The web application architecture (see Figure 3) is composed of:

- **a client:** is the main responsible for all audio analysis and can run on modern devices via web browsers. Its frontend includes audio feature extraction by Essentia.js, device microphone input stream, music harmony related functions, waveform visualization and storage management.
- **a server:** is a component in the Node.js environment and is responsible for providing the audio stream from the conversion of a YouTube video.

3.2 Graphical interface

The home page (see Figure 1) was designed to be as clear and intuitive as possible, presenting the two offered options: 1) on the left side the user can choose the key and the scale on which to practice (being able to first consult the description and the notes in it); 2) on the right side there is the possibility to insert a YouTube link of a song or backing track on which to improvise. If the musician

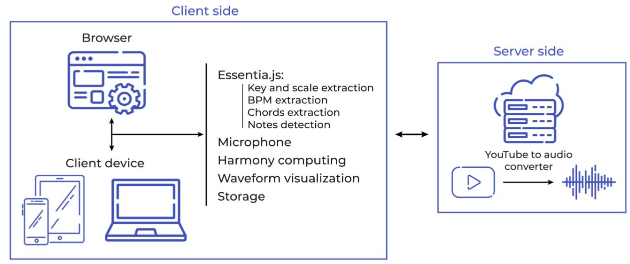

Figure 3: The architecture of the web application.

had already uploaded songs in the past, s/he can view and upload them from the bottom pane.

When the user chooses the first option, after having selected a key and a scale from the drop-down menus, the page for scale practicing with the sole instrument is displayed (see Figure 4). On the left pane of this page, the user can review the chosen key and scale, and modify them. Upon the usage the statistics of the improvisation session are shown and updated in real-time. On the right pane the notes of the scale are displayed, followed by the microphone button to start the practice session (and the possible "Previously analyzed songs" pane). While playing, the notes belonging to the scale enlarge and turn green, otherwise they are shown on the right side.

At the top right of the screen, an input box appears in which the link to a YouTube song can be inserted. This action is equivalent to entering the link in the input box on the right side of the home page, and will bring the user to the page for scale practicing with accompanying music (see Figure 5). Such a page is similar to the page for scale practicing with the sole instrument, but it features a large player with the song audio waveform in the center. Moreover, it shows the song BPM on the left side and has a toggle to show the song chords on the top. The audio waveform is responsive, users can press on it to move the playback cursor. The player controls include a volume button which shows a volume slider on hovering, or it can be pressed to mute/unmute the audio.

4 EVALUATION

4.1 Technical validation

In first place, we verified that the application worked correctly on different browsers. The validation was conducted on Google Chrome, Microsoft Edge, Mozilla Firefox and Apple Safari, which all showed to support correctly the application on both PC and mobile platforms.

Secondly, we assessed the limits in the detection accuracies. These were naturally bounded to the performances of the pitch detection algorithms of Essentia.js library. A test of note recognition accuracy was conducted by playing 360 evenly distributed notes on the fretboard of an electric guitar. Specifically, each of the 12 notes was played 30 times in 3 different musical octaves (from the second to the fifth octave) at the speed of 150 beats per minute. Results showed an average recognition accuracy of 92.2%. A tendency for wrong recognition was observed for the highest

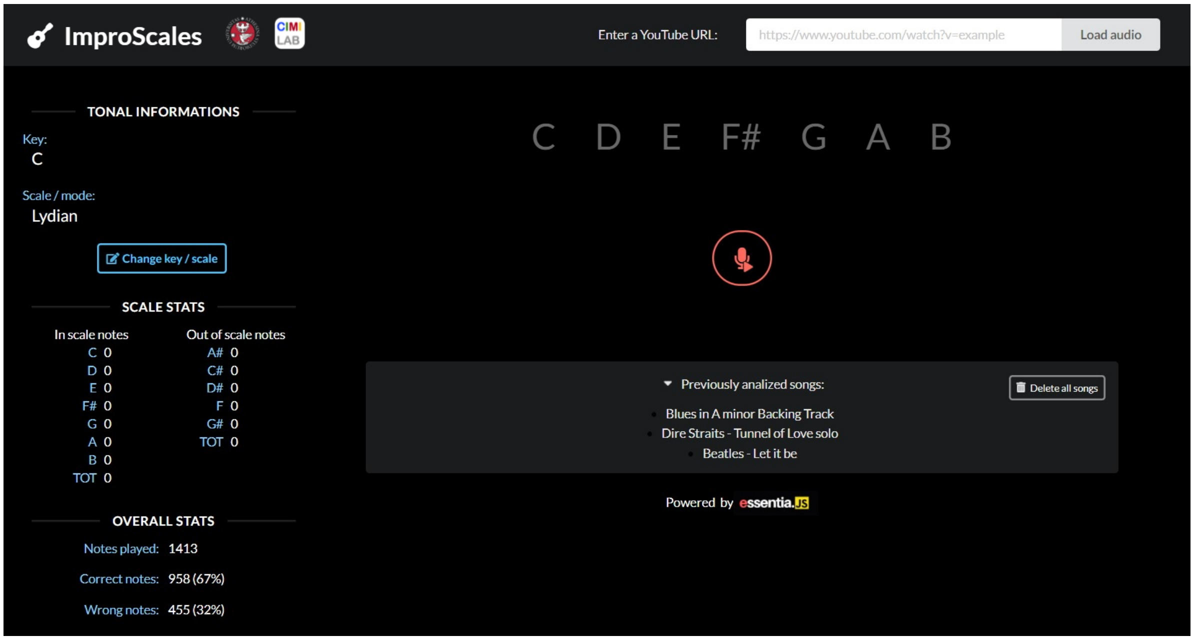

Figure 4: The page for scale practicing with the sole instrument.

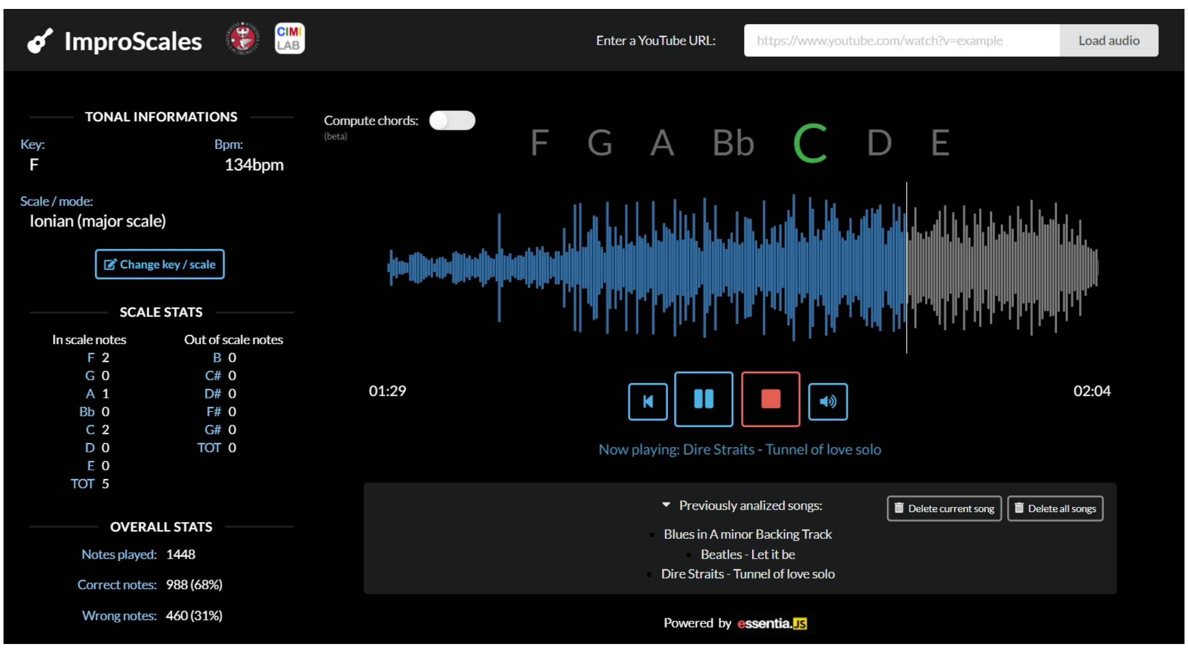

Figure 5: The page for scale practicing with accompanying music.

pitches. Nevertheless, we deemed the achieved accuracy sufficient for the purpose of testing our proof of concept prototype.

4.2 User experience evaluation

In the following, we report and discuss our findings in relation to our two research questions. Our evaluation addressed users' experience with ImproScales (RQ1) and to what extent can a system like

ImproScales promote the learning of the use of scales for improvisation (RQ2). All reported results and quotes were translated from Italian to English.

4.2.1 Participants. The user study aimed at assessing the usability of the system and participants' experience in interacting with it. A total of twelve participants took part to the evaluation (7 males, 5 females, aged between 18 and 58, mean age = 28.7, standard deviation = 12). All of them deemed themselves intermediates. None was a professional musician. We focused on intermediates rather than beginners or experts as this category of users is sufficiently acquainted with guitar playing but still needs to improve their skills, thus would reflect better the target users of the app. Six participants performed the experiment using the electric guitar, four the acoustic guitar, and two the keyboards. The experiments were conducted at participant's home. Participants took on average one hour to complete the experiment. The procedure, approved by the local ethics committee, was in accordance with the ethical standards of the 1964 Declaration of Helsinki.

4.2.2 Procedure. The evaluation procedure consisted of the following steps. Firstly, participants were debriefed about the experiment and were asked to interact with the web application. Secondly, participants were asked to use the app in conjunction with their instrument. Specifically, they were instructed to i) use the page for scale practicing with the sole instrument, selecting 3 scales of their own choice; ii) use the page for scale practicing with accompanying music, selecting 3 pieces from YouTube.

After having used the app, participants were administered a questionnaire comprising different parts. Firstly, we captured participants' experiences with the User Experience Questionnaire [15]. Such a questionnaire contains six scales: *i) Attractiveness:* Overall impression of the product. Do users like or dislike the product? *ii) Perspicuity:* Is it easy to get familiar with the product? Is it easy to learn how to use the product? *iii) Efficiency:* Can users solve their tasks without unnecessary effort? *iv) Dependability:* Does the user feel in control of the interaction? *v) Stimulation:* Is it exciting and motivating to use the product? *vi) Novelty:* Is the product innovative and creative? Does the product catch the interest of users? The questionnaire is based on a 7-point scale. In section 4.2.3, we report the ratings of the User Experience Questionnaire in the range from -3 (most negative value) to 3 (most positive value).

Secondly, we asked participants to fill in a custom "System Evaluation Questionnaire" composed by two parts. The first part concerned a set of ad-hoc questions to be evaluated on 7-point semantic differential scales (see Figure 7). The second part consisted of the following open-ended questions:

- Which of the two systems (with and without backing track) would you use more frequently? Why?
- How would you improve the app?
- What did you appreciated most in the app?

Finally, participants were given the opportunity to leave an open comment.

4.2.3 Results. **1) User Experience Questionnaire.** Figure 6 shows the mean and standard deviation of the items of the User Experience Questionnaire. According to the benchmarks reported in [24], ImproScales's perspicuity (M = 2.02, SD = 0.88) and novelty (M = 1.75, SD = 0.91) were rated as excellent, while attractiveness (M = 1.68, SD = 0.89), efficiency (M = 1.52, SD = 0.91), dependability (M = 1.68, SD = 0.91), stimulation (M = 1.5, SD = 0.9), were rated as good.

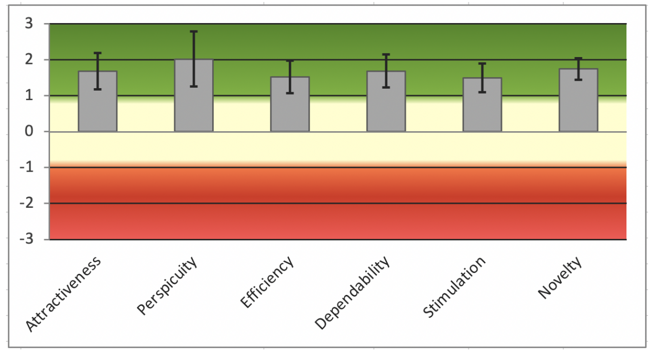

Figure 6: Mean and standard deviation of the "User Experience Questionnaire".

2) System Evaluation Questionnaire. Figure 7 shows the mean and standard deviation of the items of the custom questionnaire. As it is possible to notice all ratings are above the neutral point (i.e., 4) and most of them are high.

3) Open-ended questions. Participants' answers to the open-ended questions were analyzed using an inductive thematic analysis [7]. The analysis was conducted by generating codes, which were further organized into themes that reflected patterns, as described below.

Concept and novelty. Six participants commented to have appreciated the concept of the app along with its novelty compared to conventional learning practices or the use of other technological solutions available in the market. In particular, the possibility of simply pasting any link to songs retrieved from YouTube for automatic analysis of its content was very appreciated.

Usefulness. Both systems were deemed effectively useful by all participants, as they allow players to understand what errors are done both in real-time and a posteriori (e.g., *"The app allows me to memorize the scale and verify my knowledge by comparing the correct notes with the wrong ones"; "The app is intuitive and was very useful to me when learning scales that I was not familiar with. The feature where non-scale notes are highlighted is an excellent feature which I found very useful as well"; "I deem very useful to know which notes I mistake more frequently and which I could play more often"*). Moreover, four users commented that the app fosters learning in ways different than conventional methods (e.g., *"I appreciated the the possibility to learn the position of the nots on the guitar neck, playing freely without the canonical scales positions"; "The note visualization in real-time was useful to learn the position of the notes on the guitar neck, as I don't know all of them"*).

Preference. Seven subjects reported to prefer the system without backing track, four the system with backing track, and one expressed no preference. The main reasons for preferring the system without backing track were: i) the system was found more useful for the specific practice needs of the users, ii) it allows to focus only on the contribution of the musician; iii) it allows develop the hearing and musicality without being influenced by an

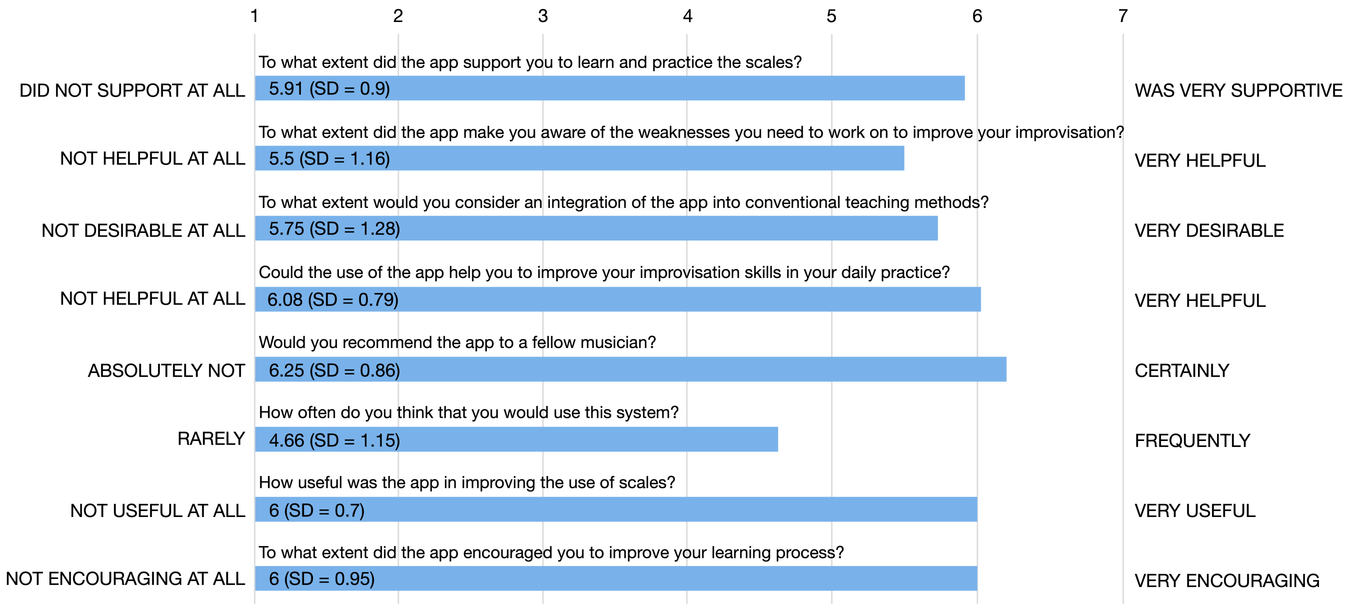

Figure 7: Mean and standard deviation of the 7-point semantic differentials in the custom "System Evaluation Questionnaire".

additional music in background. The reasons for preferring the system with backing track were ascribable to the fact that such system is more fun to use, allows to test the improvisation abilities in a scenario more similar to the real performance, and allows to practice improvisation over an underlying harmonic guide rather than being free to improvise without a reference background.

Pitch tracking issues. Two participants commented that the system was not sufficiently capable of tracking notes played at fast tempo, which forced them to slow down their playing speed (e.g., *The note tracking is very slow. I was restricted to play at a very slow speed"*).

Backing track analysis issues. Three participants reported to have noticed that the system with backing track was flawed with respect to the recognition of key and chords. Furthermore, it was noticed that the system was not able to identify more than one key for a piece containing different keys. However, those users appreciated the possibility offered by the app interface to let users amend the key and scale resulting from the automatic analysis of the music information retrieval algorithms. Another issue, reported by three participants, was that the loading time for the analysis of the wanted backing track was too long. The issues reported above were one of the factors for not giving their preference to the system with backing track (e.g., *"The second system would be more usable if it was faster, more accurate and if it could recognize different keys for different parts of a piece"*).

Feature requests. Two participants suggested to improve the app with a documentation page to better introduce users to its usage (especially for those less acquainted with music theory or even music technology). However, in general the app was deemed intuitive, easy to use and to learn. Two other participants suggested to add other features such as a metronome and a wider range of scales, including the possibility to define a scale by listing a set of specific notes.

5 DISCUSSION AND CONCLUSIONS

This study aimed at developing a new application for supporting the learning process of using scales in improvisation, which was based on state of the art web and music information retrieval technologies. Taken together, the results of the user study showed that both systems composing the app were deemed useful by participants in supporting their improvisation learning practices. As expected, the two systems correspond to two use cases, which are preferred by musicians depending on their kind of practices and learning goals.

The use case of scale practicing with the sole instrument is primarily appreciated by those musicians who do not know well the musical scales and want to learn them properly, or for those who want to freely practice without a backing track to develop their musical expressivity without being bound to a specific harmonic progression, rhythm or genre. The use case of scale practicing with accompanying music retrieved from YouTube is more appreciated by musicians willing to have a recreational music making moment, who typically already know the scales and want to improvise over a song or instrumental music.

The possibility of becoming aware of the correct and wrong notes played was very appreciated. In particular, one of the features most appreciated was the real-time visualization of the played notes, which allowed some users to better explore regions of their instrument that they typically did not use often. However, both the technical and user experience evaluation highlighted the need for more accurate real-time pitch tracking algorithms, especially capable of working in a web application.

Notwithstanding the low amount of information automatically extracted from both the music played by a musician and a song retrieved from an online repository, musician deemed the app useful, which paves the way for new pedagogical applications based on web and real-time music information retrieval technologies.

Notably, the study has some limitations. First, the not optimal pitch tracking accuracy of the algorithm used could have affected negatively some of the scores reported by participants. Secondly, the pool of participants involved was low (n = 12), all participants were Italian, and mostly were guitarists. A wider set of musicians from different countries and cultures, as well as a more diversified pool of musical instruments involved would confer the results with a higher level of generalizability.

In future work we plan to improve the app starting from some of the features requested by participants. Firstly, we plan to add a metronome. Secondly, we plan to devise a more elaborated system capable of providing more complex suggestions on how to improve a musician's improvisation capability. Furthermore, we plan to create tutorials and provide a default list of musical pieces correctly analyzed in terms of keys, key changes, and chords, overcoming the limitations of current music information retrieval methods.

REFERENCES

[1] C. Alexandraki, D. Akoumianakis, M. Kalochristianakis, P. Zervas, M. Kaliakatsos-Papakostas, and E. Cambouropoulos. 2022. MusiCoLab: Towards a Modular Architecture for Collaborative Music Learning. In *Proceedings of the Web Audio Conference*.

[2] M. D. Amico and L. A. Ludovico. 2020. Kibo: A MIDI controller with a tangible user interface for music education. In *International Conference on Computer Supported Education*. 613–619.

[3] L. Barreto, P. Taele, and T. Hammond. 2016. A stylus-driven intelligent tutoring system for music education instruction. In *Revolutionizing education with digital ink*. Springer, 141–161.

[4] M. Biasutti and L. Frezza. 2009. Dimensions of music improvisation. *Creativity Research Journal* 21, 2-3 (2009), 232–242.

[5] D. Bogdanov, N. Wack, E. Gómez Gutiérrez, S. Gulati, P. Herrera Boyer, O. Mayor, G. Roma Trepat, J. Salamon, J.R. Zapata González, and X. Serra. 2013. Essentia: An audio analysis library for music information retrieval. In *Proceedings of the International Society for Music Information Retrieval Conference*. 493–498.

[6] B. Bozkurt, S. Gulati, O. Romani Picas, and X. Serra. 2018. MusicCritic: a technological framework to support online music teaching for large audiences. In *Proceedings of the 33rd World Conference on Music Education*. International Society for Music Education.

[7] V. Braun and V. Clarke. 2006. Using thematic analysis in psychology. *Qualitative Research in Psychology* 3, 2 (2006), 77–101.

[8] A. M. Burns, S. Bel, and C. Traube. 2017. Learning to play the guitar at the age of interactive and collaborative Web technologies. In *Proceedings from Sound and Music Computing Conference*. 77–84.

[9] Albin Andrew Correya, Jorge Marcos Fernández, Luis Joglar-Ongay, Pablo Alonso Jiménez, Xavier Serra, and Dmitry Bogdanov. 2021. Audio and Music Analysis on the Web using Essentia. js. *Transactions of the International Society for Music Information Retrieval* 4, 1 (2021), 167–181.

[10] S. Das, S. Glickman, F. Y. Hsiao, and B. Lee. 2017. Music Everywhere–Augmented Reality Piano Improvisation Learning System. In *Proceedings of the International Conference on New Interfaces for Musical Expression*. 511–512.

[11] Vsevolod Eremenko, Alia Morsi, Jyoti Narang, and Xavier Serra. 2020. Performance assessment technologies for the support of musical instrument learning. In *Proceedings of the 12th International Conference on Computer Supported Education*.

[12] D. Johnson and G. Tzanetakis. 2017. VRMin: using mixed reality to augment the theremin for musical tutoring. In *Proceedings of the International Conference on New Interfaces for Musical Expression*. 151–156.

[13] T. Kelkar, A. Ray, and V. Choppella. 2015. SangeetKosh: An open web platform for music education. In *2015 IEEE 15th International Conference on Advanced Learning Technologies*. IEEE, 5–9.

[14] J. Kratus. 1995. A developmental approach to teaching music improvisation. *International Journal of Music Education* 1 (1995), 27–38.

[15] Bettina Laugwitz, Theo Held, and Martin Schrepp. 2008. Construction and evaluation of a user experience questionnaire. In *Symposium of the Austrian HCI and usability engineering group*. Springer, 63–76.

[16] V. Lazzarini, D. Keller, N. Otero, and L. Turchet. 2020. *Ubiquitous Music Ecologies*. London: Routledge.

[17] D. Menzies and A. McPherson. 2013. A digital bagpipe chanter system to assist in one-to-one piping tuition. In *Proceedings of the 2013 Stockholm Music Acoustics Conference/Sound and Music Computing Conference (SMAC/SMC), Stockholm, Sweden*.

[18] J. Nika, M. Chemillier, and G. Assayag. 2017. Improtek: introducing scenarios into human-computer music improvisation. *Computers in Entertainment* 14, 2 (2017), 1–27.

[19] F. Pachet. 2003. The continuator: Musical interaction with style. *Journal of New Music Research* 32, 3 (2003), 333–341.

[20] A. Perez-Carrillo. 2019. Violin Timbre Navigator: Real-Time Visual Feedback of Violin Bowing Based on Audio Analysis and Machine Learning. In *International Conference on Multimedia Modeling*. Springer, 182–193.

[21] S. Phon-Amnuaisuk and K. S. Chee. 2005. Interactivities in music intelligent tutoring system. In *Fifth IEEE International Conference on Advanced Learning Technologies*. IEEE, 519–520.

[22] H. Rechberger. 2018. *Scales and Modes Around the World: The complete guide to the scales and modes of the world*. Fennica Gehrman Ltd.

[23] V. Rowe, A. Triantafyllaki, and X. Anagnostopoulou. 2015. Young pianists exploring improvisation using interactive music technology. *International Journal of Music Education* 33, 1 (2015), 113–130.

[24] Martin Schrepp, Jörg Thomaschewski, and Andreas Hinderks. 2017. Construction of a benchmark for the user experience questionnaire (UEQ). *International Journal of Interactive Multimedia and Artifcial Intelligence* 4, 4 (2017), 40–44.

[25] L. Turchet, C. Fischione, G. Essl, D. Keller, and M. Barthet. 2018. Internet of Musical Things: Vision and Challenges. *IEEE Access* 6 (2018), 61994–62017.