Real-time Button Display and Chord Verification – an Interactive Learning App for the Diatonic Accordion

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Figure 1: The main author with Diatonic Accordion, using the QuetschnApp.

ABSTRACT

We present the QuetschnApp, a prototype of a digital learning environment for the Austrian diatonic accordion. The app displays the respective buttons of a music piece consecutively, and verifies the played chords using pitch detection. The prototype has been evaluated in two user-studies with 25 participants. It turned out that learning a new music piece with the QuetschnApp works well and is generally well accepted. The prototype is transferable to other instruments of the accordion family.

KEYWORDS

algorithmic hearing, pitch detection, interactive learning environment, instrument tuition

ACM Reference Format:
Celia Moosbrugger and Katharina Groß-Vogt, Marian Weger. 2022. Real-time Button Display and Chord Verification – an Interactive Learning App for the Diatonic Accordion. In *AudioMostly 2022 (AM '22), September 6–9, 2022, St. Pölten, Austria.* ACM, New York, NY, USA, 8 pages. https://doi.org/10.1145/3561212.3561218

1 INTRODUCTION

Instrumental pedagogy, as any part of society, is facing the profound change of digital transformation. This development was further fueled by the Covid-19 pandemic when instrument tuition took largely place as distance learning. Against this background, the need for new tools in the context of tuition on specific instruments has arisen. In his seminal work on instrumental pedagogy, A. Ernst [1] defined central elements for teaching an instrument: the model-method, the working-out procedure, and the assignment-procedure are three that we will refer to in the following (the others

AM '22, September 6–9, 2022, St. Pölten, Austria

ACM ISBN 978-1-4503-9701-8/22/09…$15.00
https://doi.org/10.1145/3561212.3561218

are putting-into-context, letting-discover, and dialogue with the pupil; all translations by the authors). In the model-method, the teacher acts as a model and allows the pupil to imitate his or her playing. Working-out means to guide the pupil by inviting, giving hints, or correcting him or her. Finally, the assignment-procedure constitutes of defining and evaluating tasks. It was our goal to transfer these methods to the virtual domain, where the teacher is replaced by an interactive learning environment in the form of a simple app. Obviously, this replacement has its shortcomings, and the current prototype is not meant to substitute instrument tuition completely, but rather to complement it. In the ongoing debate, Plössnig [11, 12] took up the learning fields of Ernst and completed them with digital skills. He takes the point of view that instrumental pedagogy does not have to be newly defined, but rather needs to add digital skills. We believe that pedagogical methods are not merely completed by additional digital ones. In our view, traditional methods can be re-interpreted using contemporary devices and tools. The presented prototype for the diatonic accordion is challenging this hypothesis, i.e. to transfer methods of instrumental pedagogy from real to virtual. Existing tools for digitalizing instrument pedagogy are (1) video conferencing tools for live tuition, (2) tutorials or videos for asynchronous learning – both as free online resources and within payment systems of online musical schools, (3) digital instruments that imitate real world instruments, e.g., using the smartphone's interface to play recorded instruments' sounds (e.g., Strasser Harmonika [4]), and (4) interactive learning environments that claim to teach a specific instrument by digital means. Additionally, many apps for supporting different aspects of instrument playing are available, such as metronomes or tuning apps. In our estimation, learning an instrument only in an interactive learning environment is an ambitious aim. However, supporting different aspects of learning the instrument can be substituted by virtual means and even benefit from the new medium. One such aspect is the automation of a sequence of buttons (i.e., a melody) that have to be pressed on the accordion. In the real-world, this is a time-consuming part of tuition where the teacher guides the pupil through the learning process. For popular instruments such as the piano or the guitar, many apps can be found that pursue such a goal; for instance, Rocksmith+ for guitar [16] or HoloKeys [3] for piano, which even makes use of augmented reality. For the diatonic accordion, we found two applications: one is a small-scale app from Slovenia that has historically similar instruments to the Austrian ones. It allows to display the respective keys of a piece and play along [15]. The second one is an app of a famous accordion player that was commercially successful but is not maintained any more [2]. None of the found apps is truly interactive in the sense that it verifies the chords that have been played. In this paper, we present the prototype of the QuetschnApp, a digital learning environment for the Austrian diatonic accordion. The QuetschnApp might enrich regular lessons or, respectively, support autodidacts independent of location and time to learn to play songs outside of musical schools. The instrument is introduced in Sec. 2, followed by an overview of the features of the app and details of the central algorithms. In Sec. 3 we describe the evaluations as part of a cyclic design process, and finally draw conclusions in Sec. 4.

A demo video is online at https://phaidra.kug.ac.at/o:127074 but suspended - until 2025, please mail to the authors for admission.

2 THE QUETSCHNAPP

Before presenting the QuetschnApp, we give a short overview of the Austrian diatonic accordion, as its specificities define the technical requirements of the app.

2.1 The diatonic accordion

The diatonic accordion was invented 1829 in Vienna, as part of the family of the diatonic button accordions that exist in many countries [9]. The presented work focuses on the Austrian diatonic accordion, in Styrian dialect called "Quetschn", and is henceforth referred to as diatonic accordion; see Fig. 1. It contains one keyboard on the melody side and one on the bass side, and is a single-action (i.e. bisonoric) musical instrument. This means that each button sounds differently when the bellow is pushed and when it is pulled (with the exception of only three buttons that sound the same). On the melody side, some notes are present multiple times, both within the same bellow direction and in different bellow directions. For instance, when closing, the note g´ can be found in the first and second row, as shown in Fig. 2.

The diatonic accordion is available in different tempers, but the most common are `Bb-Eb-Ab-Db`, `A-D-G-C`, and `G-C-F-Bb`. For instance, `G-C-F-Bb` means that in closing bellow direction the first row outputs triads from G major, the second row from C major, and so forth. Beside these, all tempers out of the circle of fifths are available, e.g., `G#-C#-F#-B` or `B-E-A-D`.

One further specificity of the diatonic accordion has to be mentioned. The loudest partial of a single note is usually not its fundamental, but the 3rd partial, see Pomberger et al. [13]. This fact makes polyphonic pitch detection very difficult. Pomberger et al. circumvent this problem by applying a halftone smoothing to the magnitude spectrum, with the result that the fundamental becomes the loudest partial. This approach may be applied to future versions of the QuetschnApp as well, but was not necessary as discussed below.

2.2 Features of the QuetschnApp

In early times of the diatonic accordion the instrument was nearly exclusively learnt from teacher to pupil without musical scores. In instrumental pedagogy, this principle is called imitation or the model-method [1, p. 88]. Today, there exist scores with either notes or tabulators, but there is still a tradition carried on to learn the diatonic accordion by hearing and imitating, for instance with online videos in online musical schools such as the QuetschnAcademy [5]. The QuetschnApp follows the tradition of imitation within the low-barrier access of an app (being location- and time-independent), and additionally allows for real-time feedback of the played chords. The QuetschnApp constitutes a digital learning environment for the diatonic accordion. It visualizes the respective buttons of a music piece and verifies the played chords by pitch detection. The presented prototype is based on MobMuPlat [7, 8] that allows to run PureData (Pd) [6] on Android smartphones or tablets. The code is based on two central features, as shown in Fig. 3. The first one is the best-button determination algorithm that makes it possible to choose the right buttons for display starting from a MIDI file of the musical piece. The second one is the pitch detection algorithm

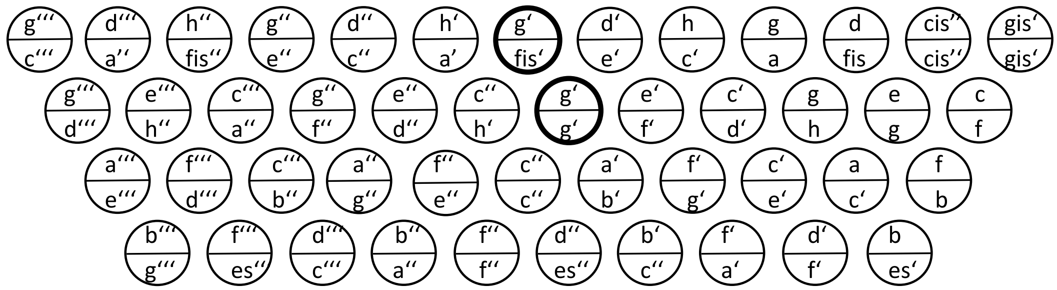


Figure 2: Tones on the melody side of the diatonic accordion with temper GCFB. As an example highlighted in bold circles, the g´ can be found for multiple tones at closing bellow direction (pushed). The upper half-circles refer to the tone produced when the bellow is pushed, the lower circle to the tone when it is pulled.

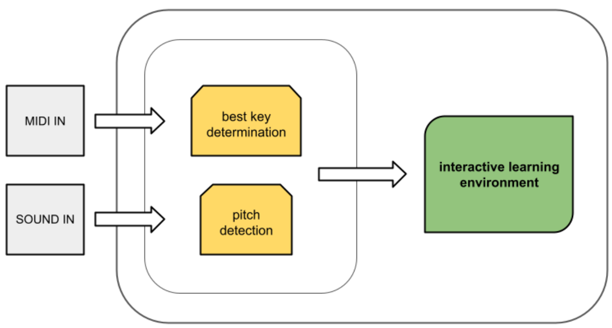


Figure 3: Central features of the QuetschnApp, an interactive learning environment: determining the best button to press starting from a MIDI file and detecting the pitch of the played chords.

that enables the verification of the played chord. This feature is optional and only active in the chord-to-chord mode, which augments the QuetschnApp to a fully interactive learning environment, as discussed below. The main features of the QuetschnApp are summarized in Table 1.

The Graphical User Interface (GUI) of the QuetschnApp is displayed in Fig. 4. When opened, the settings page is displayed (Fig. 4 in the middle). The user may adjust the right temper, define a range of the piece to be trained, and optionally activate the looping mode or the display of the fingering. Wiping to the left or right leads to the same page in different views (Fig. 4, left and right): it is the main page of the app. The left one is the version as used in tablatures of musical schools, the right one is similar to what you would see in a video or live tutorial with a teacher. The user starts with the chord-to-chord mode first and presses play to get the first button(s) of the melody highlighted. The bellow direction is visualized by different background colours shifting from brown (depicted) to yellow, and additionally by the “-> <-” and “<- ->” signs. When the user has played the correct chord, the next button(s) are marked. When the last buttons of a piece were played correctly, a pop-up mascot and a fanfare appear. When mastering the buttons’ sequence, the user may switch to the play-along mode in order to train the rhythmic structure of the piece. When the user presses “play”, after a short delay allowing him/her to get ready, a simple MIDI sound is played back, and additionally the respective buttons are highlighted.

2.3 Best-button Determination

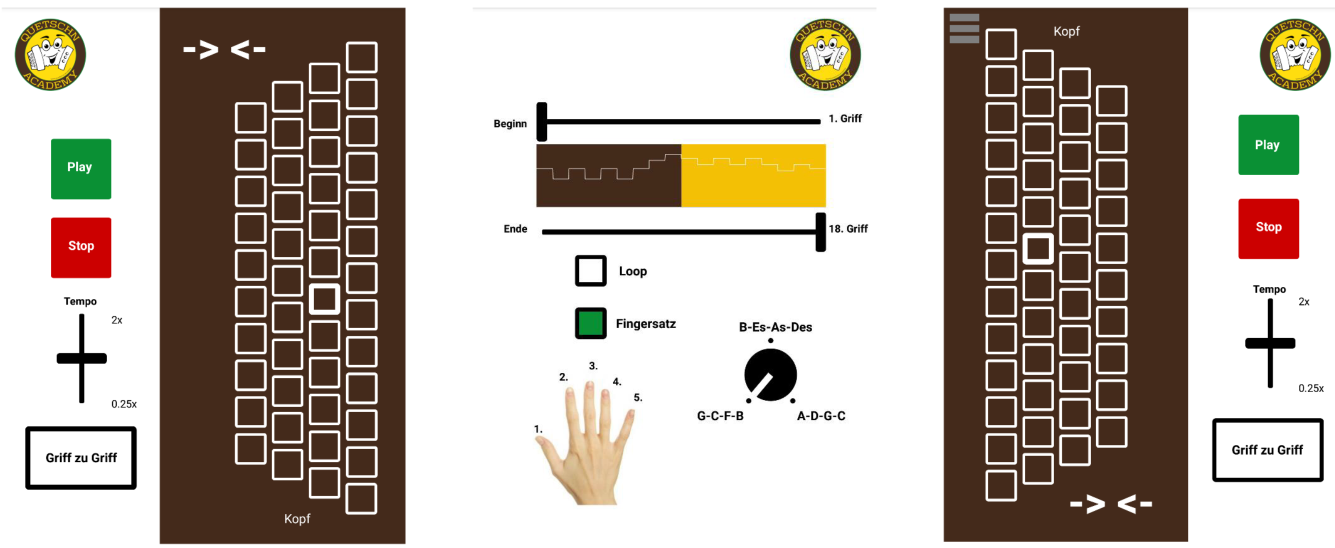
To visualize the respective buttons of each chord of a melody, we developed a button determination algorithm. The algorithm excludes only a few special cases that can be looked up in a table. Furthermore, a button map is provided where the mapping of the buttons is stored. As input, the algorithm needs the MIDI number of a tone, the number of the main row, and the bellow direction. The MIDI note alone is not sufficient, because some notes are arranged multiple times at the melody-side of the diatonic accordion (see Fig. 2). To determine the relevant button out of several options the algorithm chooses the nearest one to the main row. This is the best option known from practice because it is the easiest button for the player to reach by hand. We used an electronic diatonic accordion to write the MIDI files for a few pieces. The bellow direction and the main row are not determined by that system. Therefore, these parameters had to be appended manually, with varying effort. While a typical piece of folk music consists of three different parts that are equivalent to three main rows, the bellow direction is changing every few seconds (e.g., after two to four bars). For the presented prototype, a few musical pieces have been annotated by hand, appending bellow direction and main row to a MIDI source file. For future application it is possible to add these parameters automatically using, e.g., additional pressure sensors when recording a MIDI file on the electronic instrument. For each note, the button determination algorithm calculates the distance $d = |n_R - n_x|$ between the number of the main row n_R and the row number n_x for each possible button x. The button with minimum distance,

$$d_{min} = min_x\{|n_R - n_x|\} \tag{1}$$

defines the displayed button. In most cases, there is a unique result. In special cases, however, it is possible that two buttons produce the same result. For example, as shown in Fig. 2, the tone c’ in bellow opening direction is provided by $n_1 = 1$ and $n_2 = 3$. With main row $n_R = 2$, the result is ambiguous. In this case, experienced players of the diatonic accordion would choose different buttons,

Feature	Function	GUI page	GUI element
Temper setting	Adjust the right temper of the instrument	Settings	Triplex rotary button
Display Fingering	Display the suggested fingering as numbers on the keyboard (main page)	Settings	On/off button
Part selection	Select starting and end point of the exercise	Settings	Dual slider on track bar
Looping	Loop the selected part	Settings	On/off button
On-off-buttons	Play/pause and stop buttons (when stopped will re-start from beginning)	Main	Buttons
Mode selection	Shift between play-along mode and chord-to-chord mode; the chord-to-chord mode activates pitch tracking	Main	A/B button
Display bellow direction	Change colour and show arrows for opening and closing the bellow	Main	Background colour and display
Key display	Change colour of respective button(s) on the keyboard	Main	Colour change
Tempo change	Vary the tempo of the exercise	Main	Vertical Slider
Success message	The app's mascot and a fanfare appear at the end point of the exercise	(Overlaid)	Pop-up picture and sound

Table 1: Overview of the features of the QuetschnApp, their function, and indication of their appearance indicating the GUI page and GUI element.



(a) (b) (c)

Figure 4: Graphical User Interface (GUI) of the QuetschnApp. These three pages can be wiped sideways. The main GUI page is available twice, in mirror-inverted view, with two different views of the keyboard ((a) and (c)). The central page is the starting page with settings: defining a range for the exercise from beginning ("Beginn") to end ("Ende"); turn looping and display of fingering ("Fingersatz") on/ off (with a depiction of fingers to numbers), and setting the temper of the instrument. On the main page, the mode can be changed between play-along and chord-to-chord ("Griff-zu-Griff"). Above, the vertical slider allows to change the tempo of the exercise between 1/4th and double tempo. Play/ Pause and Stop buttons allow to begin and end the exercise.

depending on their individual style. For beginners, it is important that the QuetschnApp displays only one option, in order to allow a consistent learning experience. Therefore, only the button with the lowest row number is displayed (in the above example, n_1).

2.4 Chord-to-chord mode: pitch detection

The chord-to-chord mode is based on the pitch detection as described below. By starting this mode, the first button is highlighted on the display. The program waits until the correct chord is detected through the microphone, and then proceeds to the next chord. At this stage, the pitch detection has only been implemented for the melody side, neglecting the bass side.

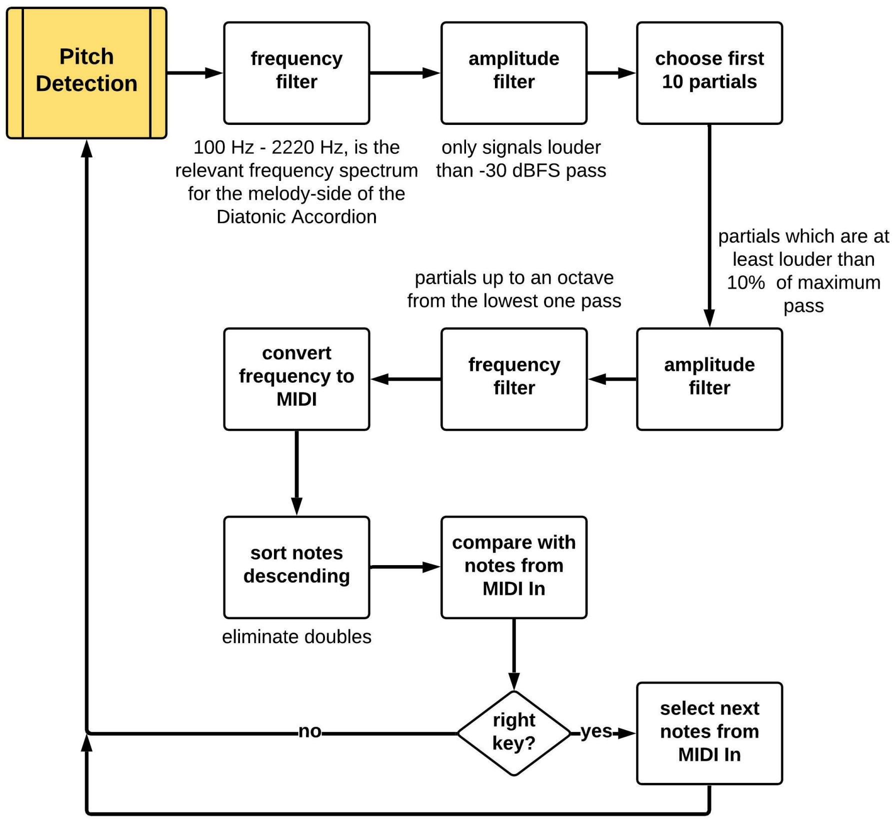


Figure 5: Flow chart the pitch detection algorithm in the QuetschnApp.

The polyphonic pitch tracking algorithm of the QuetschnApp is depicted in Fig. 5. The partial tracking itself is based on the `sigmund~` object in Pd[1], working on FFT analysis windows of 2048 samples with 128 samples overlap. The detected partials are sifted through several processing steps, until only the fundamentals of the played tones remain. In a first step, only partials within the relevant frequency range of the melody side of the diatonic accordion (100 Hz to 2220 Hz) are passed. From the remaining partials, only the (up to) ten most prominent ones which exceed a minimum threshold level of -30 dBFS are considered as candidates for the tones of the played chord. These are further reduced to only those whose amplitude equals at least 10 % of the strongest partial. Subsequently, the algorithm uses a simple logic to sort out the fundamental frequencies of simultaneous notes, without the need of halftone smoothing as was suggested by Pomberger et al. [13]. Keeping in mind that the QuetschnApp is targeted at beginners, it is assumed that only musical pieces from the standard repertoire of the diatonic accordion are played. As the chords of standard pieces usually span less than an octave, all detected partials that are less than an octave above the lowest one are identified as fundamentals of other (simultaneous) tones. Each of the obtained frequencies is then rounded to the frequency of the nearest MIDI note in the given temper, to allow an identification of the played notes. If these detected tones match the required ones of the current chord for a period of at least 219 ms, the system proceeds to the next chord and the pitch detection algorithm is restarted with the next analysis window. The relatively long period of 219 ms was chosen to ensure that the pupil did not randomly press the right button. The disadvantage of this period is the time delay for the more advanced learning level. However, the chord-to-chord mode is a first learning step to memorize relevant fingering and anyhow neglects the rhythmical structure of the piece, which is subsequently trained in the play-along mode. When the right button was played for 219 ms, the system expects a pause of 13.7 ms (with level below -40 dBFS). This pause is essential in case of repeating notes within the melody to let the pupil know that the button should be played again.

[1]Unfortunately, it was not possible for the authors to find literature on the sigmund object. Its author, Miller Puckette, only described its predecessor, fiddle [14]. According to a colleague who asked Puckette personally during a conference, "sigmund was the best pitch tracker he had programmed so far" – unfortunately no further details have been unveiled (https://www.mail-archive.com/pd-list@iem.at/msg30589.html). The interested reader is referred to the source-code of Pd: https://github.com/pure-data/pure-data

3 EVALUATION

The prototype was tested during the design process in think-aloud user tests with three rather novice accordion players. Following to these pilot tests, the prototype was further enhanced and tested in two larger studies as described below.

3.1 Study Design

The study was designed in two different settings: a short-term study (STS) with 20 participants at two different accordion workshops and a long-term study (LTS) with five participants at their homes. A statistical analysis was only carried out for the short-term study, while the long-term study yielded qualitative feedback. Two music pieces for beginners were chosen and prepared as described in Sec. 2: the main theme of the first movement of W. A. Mozart's Serenade No. 13 ("Eine kleine Nachtmusik") and the refrain of "Griechischer Wein" by Udo Jürgens. Both pieces are widely known in Austria and easy to play, but neither is part of the standard repertoire of the diatonic accordion, so it was unlikely that the participants had played them before. The procedure of the STS was as follows. First, the app was explained to the participants within five minutes, then they had the opportunity to test the QuetschnApp for an open amount of time (between 10 and 60 minutes). Afterwards, the test subjects answered an online questionnaire that was designed using 7-point Likert items with labelled edges (from very good to very bad), checkboxes, and open description fields.

In the LTS, five test persons were introduced to the app and given a pre-installed tablet to their homes for a period of 7 to 14 days. Then, the main author of this paper led a structured interview with each test person that took roughly 45 minutes, focusing on the same research questions as assessed in the online questionnaire. These criteria roughly follow Norman's [10] classic factors for good design that are aesthetic beauty, reliability and safety, usability, cost, and functionality:

- Functionality: reaction of the chord-to-chord mode; quality of sound in the play-along-mode
- Learnability: possibility to learn a new piece with the app (in each mode)
- Affective Response: feeling to use the app (in each mode); motivation of using the app (compared to other types of tuition)
- Usability: the intuitiveness of the GUI; if and why (or why not) the features for fingering and looping have (or haven't) been used; which keyboard view was preferred
- General acceptance: readiness to use the app; how to use it (uniquely or in addition to other types of tuition)
- Background: duration of app testing; experience of playing the diatonic accordion (years of playing, three last pieces learnt, type of tuition: online/ musical schools, personal tuition); tech-savviness (use of smartphone etc.); the willingness to pay for the app; age; gender; suggestions to improve the app.

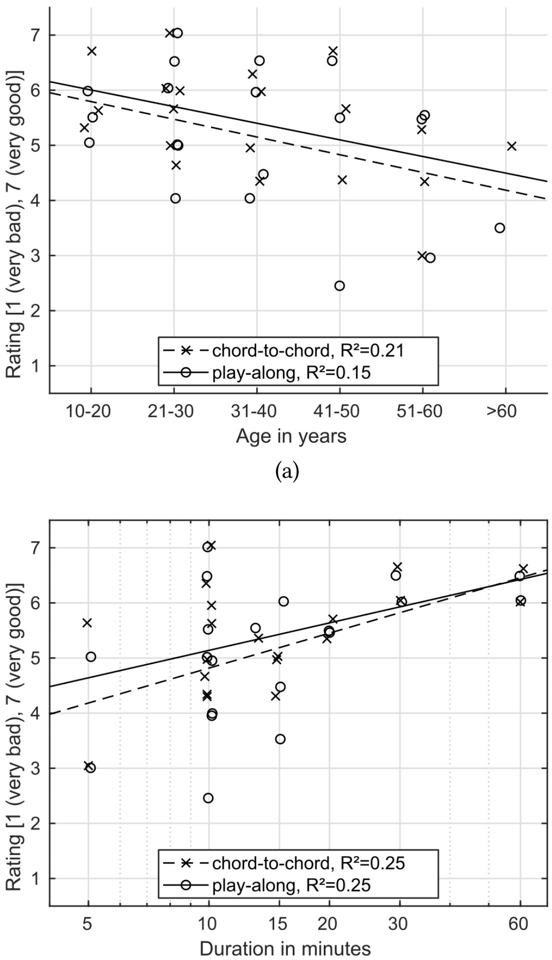
3.2 Results

The results of the online questionnaire were analysed quantitatively in Matlab. Test persons were mostly male (85%), between 10 and 60 years old (the most participants from the group of 31-40 years). 17 out of 20 persons stated they would use the app, one of them even solely, the others in addition to other forms of tuition. We aggregated data from the Likert items to achieve a full Likert scale by averaging over all items with equal weight. Additionally, it proved useful to aggregate only some selected questions on the same topic, similar to the overall scale. We combined the rating of the learnability and the affective response to an individual scale for each mode. The three so-created scales (overall, chord-by-chord, and play-along) were assumed to follow a normal distribution, as the Lilliefors did not reject the null hypothesis of normally distributed data at the 5% level. On average, the app achieved an overall rating of 5.31 (standard deviation SD=0.86). According to a one-tailed t-test on the individual participants' ratings, this is significantly better than 4 or neutral (t(19)=6.79, p<=0.001). This overall rating correlated significantly with the participants' age ($R^2 = 0.21$). Comparing the older and the younger half of the participants, we find that younger test persons rated the app significantly better than older ones; a fact that might be expected (t(18)=-1.87, p=0.039). The Likert scales of the chord-to-chord and play-along mode achieved average ratings of 5.40 (SD=0.98) and 5.15 (SD=1.24), respectively. Both were rated significantly better than neutral (t(19)=6.41, 4.16, p<=0.001). While the average rating of the chord-to-chord mode was slightly higher than that of the play-along mode, this difference was not significant (t(19)=1.52, p=0.072). The scales of both modes are plotted against the participants' age in Fig. 6(a) and the time they spent for testing the app in Fig. 6(b). A linear regression suggests a similar trend for both modes. For both modes, the participants' ratings decreased with increasing age (chord-to-chord: R^2=0.15, play-along: R^2=0.21), as shown in Fig. 6(a). For the chord-to-chord mode, ratings of the older half of the participants were significantly lower than those of the younger half (t(18)=-1.75, p=0.048). For the play-along mode, this effect was not significant (t(18)=-1.60, p=0.064). As suggested by Fig. 6(b), an increased test duration generally led to an increased rating, for both modes, respectively (both $R^2 = 0.25$). Splitting participants half-half into short-time and long-time testers, however, didn't lead to a significant difference in ratings; neither for the chord-to-chord mode (t(18)=0.91, p=0.187), nor for the play-along mode (t(18)=1.49, p=0.076). Finally, we also compared the rating to the experience of playing the diatonic accordion in years; results are not significant but show a tendency that less experienced players rated the app higher. This might be related to the fact that very simple pieces have been chosen for the evaluation study which were too basic for advanced players.

As shown in Fig. 7, the participants stated to be equally motivated when using the app, comparing this form of tuition to either personal lessons or video lessons.

Answers of the usability questions revealed a few things that are important when the app is further developed. For instance, half of the participants preferred one keyboard view, the other half the other one; therefore, both views would have to be kept in future versions. The loop function was overlooked by many participants and should be highlighted better. The fingering was well accepted. The questions addressing the functionality proved that the main features, i.e. the verification of chords and display of the best button, worked well.

In the LTS, five persons tested the app for a duration of 7 to 14 days and were interviewed afterwards, three of them male, all



(a)

(b)

Figure 6: Answers of each participant for rating learnability and affect of the app averaged on a continuous Likert scale (calculated from weighing each item and averaging over them). (a) shows the dependency of the rating towards the age of the users, (b) towards the duration the user has tested the app.

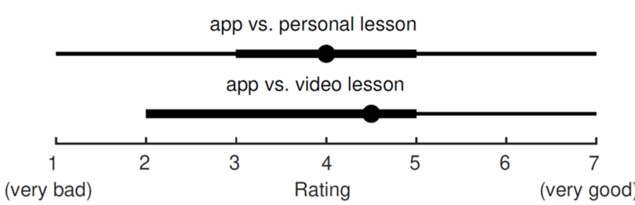


Figure 7: Motivation of using the QuetschnApp as compared to personal tuition and video lessons. The median value is marked with a dot, the range for 25% and 75% percentile as bold bars, and total range of answers as thin bar.

between 20 and 60 years old. Qualitative feedback confirmed the findings above but gave much more insight into individual details. For instance, while the chord-to-chord option was honourably mentioned, feedback revealed that the reaction thresholds of the pitch detection sometimes led to perceived leaps of the app. Comparing the app to other forms of tuition, subject 2 stated for instance *"I learned it harder than from the videos, because if I see a real hand moving I can cope better than if I only see a highlighted dot"*. On the other hand, subject 3 mentioned the better and more structured way to learn a piece. Subject 1 admitted that *"if you are used to learning videos, you need to readapt [...], but after having learned two or three pieces with the app, I think you can learn with it well and effectively."* (All translations by the authors.) Three subjects complained about the less personal approach in the app as compared to other forms of tuition, while two did not mention this fact. A solution could be a wizard that guides through the app; this idea was taken up by one test person. Repeated suggestions to ameliorate the app included incorporating the bass system (4 subjects), pre-defining learning phrases (3 subjects), and storage of the chosen temper's setting (2 subjects).

3.3 Discussion

The above results show that the QuetschnApp is well accepted by possible users. Already in the current form as a prototype, it proved to be functional and user-friendly. The data shows interesting correlations, some of which may be expected: for instance, younger people are more open to using the app. Interestingly, the duration of using the app also increases the rating. This has only been tested quantitatively within the short-term experiment, where people used the app up to 60 minutes (and many testers less time). Qualitative results from the long-term study show that there is no sign of fatigue even when using the app repeatedly for one or two weeks; therefore the result of increased appeal of the app with longer usage is promising. Both modes, the chord-to-chord mode and the play-along mode have been rated similarly well. While we first expected to find a statistical difference, where the chord-to-chord mode would have been rated higher than the play-along mode, their equal rating is understandable. Both modes are needed to train all aspects of a piece; first, the interactive mode gives the user time to find the correct button(s), then, in the play-along mode, the timing can be trained. The overall rating of the motivation to use the app as compared to other forms of tuition is not very high but it is at least equal to the neutral rating. It can be concluded that using the app is perceived similar to other forms of tuition, and is at least not inferior to video tutorials. Most test persons were ready to use the app as a complementary tool to their other tuition.

4 CONCLUSIONS

We presented a prototype of an interactive learning app for the diatonic accordion in the form of a simple app. It allows the user to practice the correct and –in case of several options, best– buttons to press within a melody chord-by-chord, verifying the sound. The pitch tracking is based on standard algorithms but applies them in a smart way, exploiting the specificities of the diatonic accordion and its literature, which allows for correct verification even for chords. Furthermore, the user can play along to the app, following the highlighted buttons, and thus train the rhythmical structure of the piece. A MIDI file of the melody serves as input, with a few data that have to be appended manually at the current stage of the prototype.

We have considered technically more advanced options, such as augmented reality – e.g., projecting the correct buttons on the real accordion's keyboard. However, such a solution is both technically much more effort and also less usable, as the accordion player has no unobstructed view on the keyboard. The app allows for three important elements of instrumental pedagogy: it gives a model that can be imitated, it allows to define tasks and control them, and it allows the pupil to work out a piece by him- or herself. The simple app solution brings together advantages of digital learning, such as the freedom of time and space, the inexpensiveness (as compared to real tuition), and making use of psychological mechanisms of reward, as e.g., are known from social media or video games. The prototype was evaluated both quantitatively (in a short-term experiment) and qualitatively (in a long-term in-home setting) in two user tests. Results assess different factors, overall affirming a good functionality and usability of the app. Compared to other forms of tuition, notably video lessons as direct competitor to the proposed learning environment, it even performed slightly better. We found dependencies with the age of the test persons, which is not surprising, i.e., that younger ones rated the app higher. As a promising result, the app was assessed better the longer is has been tested. The experience of having played the diatonic accordion might have an influence on the rating (less experienced rated higher) but this fact was not significant. It can also be understood as the chosen pieces for the user test were very basic and thus the gain for experienced players might not have been obvious. At its current state, the QuetschnApp may already support regular tuition for beginners or, respectively, be used by autodidacts to practice individual pieces.

ACKNOWLEDGMENTS

Thanks to all participants of the experiment and the QuetschnAcademy for their support.

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