Songs in Music Education: Design and Early Experimentation of a Web Tool for the Recognition of Harmonic Changes

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Abstract: This paper deals with *Harmonic Touch*, a Web platform designed to foster the practice of tonal harmony also in young children. The work focuses on one of the experiences provided by the framework, namely the gamification of harmonic change recognition in songs. The platform, specifically equipped with new features to accommodate the needs of teachers during the COVID-19 pandemic, has been tested in two Italian schools in February 2021. Early experimental results about the main difficulties encountered by the children during the games are presented and discussed.

1 INTRODUCTION

The Coronavirus disease 2019 (COVID-19) pandemic pointed out suddenly and with little room for doubts the importance of the use of communication and information technologies in educational contexts. Teachers of all types and levels have been forced to learn distance-teaching technologies and change their working habits overnight, often without any preparation. As a consequence, learning technologies have gained much more attention than before, and a growing number of teachers are eager to discover new ways to integrate technology into their daily pedagogical practices.

Moreover, the atmosphere of uncertainty that is characterizing school activities makes the use of online educational platforms extremely useful and functional to various forms of blended learning. As a matter of fact, web-based tools allow regular school work to be easily complemented with online activities outside the school, and, in case of school closure, they can fill the gap by ensuring continuity to educational activities.

In this context, we have released a Web prototype designed and implemented in a pre-COVID-19 era. It adopts the principles of gamification to foster the development of a number of tonal-harmony abilities and competences. The prototype has been tested in two Italian schools in February 2021, in a period characterized by lessons given partially in presence and partially from remote. Primary-school teachers decided to focus only on one of the experiences offered by the platform. In this activity, well-known songs are employed to make children detect harmonic changes, i.e. the timed occurrence of new chords. The experimental setup starts from the assumption that popular music is a vital part of children' lives. Although the use of popular music in schools has aroused over the years a wide debate among educators (Woody, 2007), the changes in the educational approach, the necessity of facing more informal education styles and of reshaping the contents of music programs are sufficient reasons to overcome any contraindications (Dunbar-Hall and Wemyss, 2000; Hebert, 2011). Popular music has the power of engaging children in social and emotional learning, a set of skills that promote children' well-being and enhance cognitive performance (Campayo–Muñoz and Cabedo–Mas, 2017). Beyond these important educational features, songs have a clear and sound musical structure. Choruses, refrains and bridges with their standardized functions and durations help the perception of melodic and harmonic elements, and for this reason are easy to spot and memorize.

The remainder of the paper is structured as fol-

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lows. Without claiming to be exhaustive, Section 2 mentions other categories of Web tools for music education, and for tonal harmony specifically. Section 3 shortly describes the milestones that brought to the current release of *Harmonic Touch*. Section 4 explains the role played by harmonic rhythm in the perception of music. Section 5 presents the design principles and the graphical aspects of the Web interface for the experience under exam. Section 6 describes the early results collected in the first month of experimentation. As reported in Section 6.3, the platform has been equipped with new materials and functionalities, with customized work spaces for teachers and students. User performances are shown in Section 6.4. Section 7 discusses the results collected during the early experimentation phase. Finally, Section 8 draws the conclusions and presents the future perspectives and the expected evolution of the project.

2 RELATED WORKS

The World Wide Web offers many platforms and tools for music education. Based on their functionalities and educational objectives, they can be subdivided into various categories:

1. Online music studios, which provide users with the functionalities of music sequencers, including music loops and sounds for song creation (e.g., *BandLab*,[1] *Soundtrap*,[2] *Groovy Music Cloud Edition*, and *Soundation*[3]);
2. Music performance platforms, which offer some practical tools to help students learn how to play an instrument or sight-read music at distance (e.g., *SmartMusic*,[4] *Doozzoo*,[5] *PracticeFirst*,[6] *Sight Reading Factory*,[7] and *Yousician*[8]);
3. General music education platforms for developing listening skills, theory, and composition (e.g., *BrainPOP Arts and Music*,[9] *PBS KIDS Music Games*,[10] *Classics for Kids*,[11] and *Focus on Sound*[12]);
4. Music notation and creation platforms (e.g., *Flat*,[13] *Noteflight*,[14] and *O-Generator*[15]);
5. Music theory and ear training platforms (e.g., *EarBeater*,[16] *Musictheory.net*,[17] and *Musition*[18]).

Even if the present review is far from being exhaustive, it can provide a broad idea of the educational offer for music education currently available on the Web.

The first observation is that nearly all the mentioned platforms are not free, and, consequently, they require the purchase of a premium access to fully benefit of the services offered. If, on one side, paid services can guarantee a good quality of contents and performances, on the other side they do not respond to the needs of students and teachers who still need to be encouraged in the use of learning technologies.

As far as tonal harmony is concerned, theoretical knowledge is usually embedded inside music theory programs. The typical approach of web platform is to provide an online version of traditional music theory books, possibly augmented through the integration of interactive tools for chord calculation or identification. The targeted audience is made of music-theory students engaged in formal learning programs. For this reason, such tools can be profitably applied to the academic study of harmony, but they are not suitable for children or adults interested in understanding the phenomenon rather than the theory behind it.

A less formal approach is employed in the *Hookpad Musical Sketchpad*,[19] a software where the chords of a song are displayed under a piano-roll window by employing traditional chord notation and different color codes for each chord. The piano-roll interface can be modified by changing pitches, keys, meter, tempo and chord progressions.

Another interesting tool for the study of harmony is *Mapping Tonal Harmony*,[20] a software which displays in real time the movement of chords in the harmonic space. It can also be used for very complex musical pieces both in classic and jazz style, but it is suitable for professional rather than amateur use.

[1] https://edu.bandlab.com/
[2] https://www.soundtrap.com/edu/
[3] https://soundation.com/
[4] https://www.smartmusic.com/
[5] https://doozzoo.com/
[6] https://www.musicfirst.com/applications/practicefirst/
[7] https://www.sightreadingfactory.com/
[8] https://yousician.com/
[9] https://www.brainpop.com/artsandmusic/
[10] https://pbskids.org/games/music/
[11] https://www.classicsforkids.com/
[12] https://www.focusonsound.com/
[13] https://flat.io/
[14] https://www.noteflight.com/
[15] http://www.o-generator.com/
[16] https://www.earbeater.com/
[17] https://www.musictheory.net/
[18] https://www.risingsoftware.com/musition
[19] https://www.hooktheory.com/hookpad
[20] https://mdecks.com/mapharmony.phtml

3 BACKGROUND WORK

Under the pressure of the dramatic uncertainty and discontinuity that is characterizing the life of school institutions in Italy, we publicly released *Harmonic Touch*, a Web platform designed and implemented a few months before COVID-19 pandemic (Avanzini et al., 2020). The original idea had been presented and discussed during a workshop titled "Didattica della musica e linguaggi digitali" (i.e., music education and digital languages) in occasion of the 2nd edition of Fiera Didacta Italy, Florence, October 18-20, 2018 (Avanzini et al., 2019a). The audience, mainly composed by primary and lower-secondary school teachers, had the opportunity to test the early prototype and make remarks that guided a later re-implementation.

Harmonic Touch aims to drive the attention of teachers towards the possibility of using tonal harmony features in music education even from a very early age. In order to achieve this goal, the platform offers a number of activities following the principles of gamification. The user is not pushed towards gaining theoretical knowledge, as in formal music education, but rather to develop harmony awareness through musical perception.

The platform currently presents 3 different experiences:

1. The first experience deals with the perception of implied harmony, where the user is asked to listen to a music excerpt and try to pick the implied harmony - the tonic - from a set of 6 chords representing the harmonic space. The implied harmony is the chord that best fits all the melody excerpt;
2. The second experience deals with the detection of the onsets of the harmonic changes under a melody while the tune is playing. This kind of exercise is the focus of the present paper, so it will be described in detail in Section 5.2;
3. The third experience consists in melody harmonization. After carefully listening to a melody and exploring the harmonic space, the user is asked to click on the chord sequence that best fit the melody. This type of exercise is a combination of the previous two. In our vision, it represents the final step on the way towards the development of tonal harmony awareness.

For this experimental session, we decided to focus our attention on the second experience, namely the recognition of harmonic changes. Being the most playful thanks to its gamification features, it has been positively accepted by school teachers and enthusiastically welcomed by students.

4 HARMONIC RHYTHM

Harmonic rhythm plays an important role in rhythmic and melodic perception, as well as in the segmentation process that governs the way listeners interpret and group surface musical events (e.g. the notes of a melody).

Harmonic rhythm has been defined by as the "underlying changes in harmony" (Burkat, 1944) or "the perception of rhythm that depends on changes in aspects of harmony" (Swain, 2002). Although the latter definition implies that the perception of harmonic changes may depend on various musical elements, such as timbre, musical style, the leading of the bass line, chord density and texture, for the purposes of the educational activities described in this work we focus only on two main aspects of harmonic rhythm. As described by Dawe (Dawe et al., 1993), harmonic rhythm can be considered in two different ways: as the sequence of the onsets of different harmonies, or as a "composite rhythm" that is formed by a sequence of events belonging to the same chord. This is the case of the melody of the nursery rhyme "London bridge" which, despite its simplicity, shows an unexpectedly complex underlying structure. The arcs in Figure 1 embrace the 2 semiphrases that form the melody; they are perfectly regular and symmetric. The underlying structure of the harmonic rhythm, conversely, presents different durations: 2 bars tonic (T), 1 bar dominant (D) and, again, 1 bar tonic (T). The same structure is repeated in the second semiphrase. However, as the same chord (T) ends the first semiphrase and begins the second, the overall duration of the third chord is 3 bars. Thus, a regular $4+4$ structure is superimposed to an irregular harmonic rhythm $(2+1+3+1+1)$. This is due to the effect of composite rhythm (shown in brackets in Figure 1), which happens whenever the rhythmic accent expected at the beginning of a new bar is not matched with a change in the harmony. Examples are provided in bars 2, 5, and 6 of the excerpt. The regular structure of the 2 semiphrases makes the rhythmic accent at bar 5 particularly important but, in spite of this, there is no change in the harmonic rhythm. This example demonstrates how the perception of a simple nursery rhyme can hide a complex harmonic structure, and what is the role of harmonic rhythm in building such a richness of musical events.

As theorized by Lerdahl and Jackendoff (Lerdahl and Jackendoff, 1996), tonal music is built through the superimposition of 4 main layers, each containing different musical elements. The most superficial is the *grouping structure*, which refers to the patterns created by the notes of the melody (themes

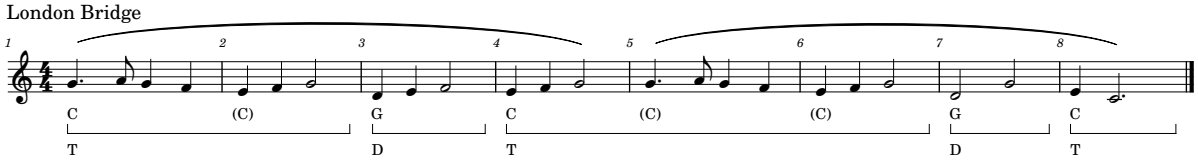

Figure 1: Harmonic changes of "London bridge". Slurs embrace 4-bar semiphrases. The lines below chord symbols indicate the occurrence of chord changes and the extension of the corresponding harmonic areas. Composite rhythm is expressed by bracketed chord indications at bars 2, 5 and 6.

and phrases). By applying the Gestalt theory principles of similarity, proximity and symmetry (Ellis, 1999), listeners are able to partition a melody into small segments according to the perception of beat accents and short-term memory (Bigand, 1993). At lower levels, there are the *metrical structure*, which considers the organization of strong and weak beats, and the *time-span reduction* and the *prolongational reduction*, which represent structural accents of musical events and tension-relaxation dynamics, respectively (Hansen, 1011).

The process of melody segmentation is not only a cognitive representation of tonal melody. It has also been employed as a computational model for the description of musical activities and for the accomplishment of musical tasks, such as music query and music information retrieval (Zhu and Kankanhalli, 2004; Hirai and Sawada, 2019).

In the case of the second experience of *Harmonic Touch*, we provide a segmentation of the melody based on the occurrence of a new chord instead on the metrical organization of the melody. As shown by the case of "London bridge", this can increase the level of complexity in the musical perception, forcing the listener to distinguish between metric and harmonic accents. This is one of the skills targeted by the second experience of *Harmonic Touch*.

5 THE WEB TOOL

Harmonic Touch is a free and cross-platform tool, currently supporting Italian and English language. It is available at the following URL: http://harmonictouch.lim.di.unimi.it/.

The front-end section and the underlying database that manages accounts and gathers performance data have already been designed and released. The back-end area at the moment of writing is still under development, currently supporting basic account options (such as password change) and, for teacher accounts only, the configuration of classes and the selection of exercises. The personal preparation and upload of new materials through the Web interface, very useful functions in a crowd-sourcing perspective, have not been developed yet.

5.1 User Accounts

The landing page lets the user enter his/her credentials. Different user types are supported: an administration account reserved for developers, a test account for authorized beta testers, an anonymous account, a teacher account, and, finally, a student account. For the goals of this paper, only the last three types will be described.

The teacher account grants access to all the experiences and exercises, so that the educator can listen and test them in order to select the most suitable ones. The back-office area lets the teacher configure each class and assign it a specific subset of exercises, also determining the level of difficulty for the exercise. Even if a default difficulty level has been assigned by domain experts to each piece belonging to the second experience, such a value is currently under investigation and should be considered a placeholder; determining which aspects (e.g., the length of the piece, its tempo, the regularity in harmonic changes, the type of chords, etc.) have an impact on the perceived level of difficulty is one of the goals of the experimentation, as discussed later.

The student account gives access to the experiences and exercises selected by the teacher for the class the student belongs to. In other words, a student can see only a specific subset of the song dataset.

Finally, the anonymous account has been conceived to let a generic user experience the platform in all its aspects and exercises with no need to be registered. Performance data from anonymous players are collected as well, but, in general, they do not allow to make inferences, since the account is not linked to a single user, and the aims of accesses can be very heterogeneous, ranging from curiosity to the exploration of otherwise protected materials. Concerning the latter aspect, teachers involved in early experimentation discovered that their students had learned how to overcome the limited piece selection imposed for their class by using the anonymous account. In the future, also the anonymous account will present a small selection of songs for demonstrative purposes.

5.2 Game Play for Experience No. 2

In order to play Experience No. 2, the user has to complete a 4-step process: i) piece selection, ii) pre-game listening activity, iii) game play, and iv) game results. These steps are shown in Figure 2.

After selecting a piece from the list, in the second step users can listen to it as long as they need in order to get acquainted with the tune and try to locate chord changes.

The gaming experience starts in the next step. The audio track has been segmented into n segments, each one corresponding to a musical chord; consequently, harmonic changes are $n-1$. The interface presents a treasure map with a dashed path connecting n nodes. The first node, not numbered, serves as the start button; the remaining nodes are in correspondence with timed harmonic changes. When the user clicks over a node, music is played from that time position.

Figure 2: From top to bottom, the 4 steps for Experience No. 2.

The ideal behavior, i.e. the one that brings the player to win with the maximum score, consists in clicking over nodes step by step, in the right order and at the right moment (namely when the chord change occurs). A tolerance of ± 0.5 s centered on the correct timing has been introduced to manage delays and avoid frustration. Tolerance defines the range within which user's click may fall while still being acceptable.

When trying to detect the harmonic change, the user has two possibilities of error: anticipated and delayed clicking. The former case comes from the perception of a chord change when the tonal area remains unaltered, and it implies a sudden jump to the new segment of the song (often, the step right ahead the current one in the dashed path). The latter scenario refers to the opposite situation, namely the occurrence of a harmonic change not detected by the user; in this case, after a short fade-out effect, music stops waiting for any user action. Please note that, while anticipated clicking is a type of error that the platform simply acknowledges (by playing an error sound, forcing a jump in playback, and decreasing the score), delayed clicking becomes evident to the user due to the absence of sound, thus pushing to take an action.

In a gamification approach, score is a typical means to increase engagement and push players towards better performances. For this reason, each piece has been associated with a maximum score $s = 100 \cdot (n-1)$ points, where n is the total number of tonal areas in the song. A click over the right node within the ± 0.5 tolerance interval adds a score which is still positive, but reduced on the base of the absolute distance from the right timing: each 0.1 s, the 100-points original amount is cut by 25 points. Clicking outside the tolerance window and/or on a wrong node implies a 10-point penalty. Values of time tolerance and score increments/decrements are parametric, so, in a future evolution of the platform, they could be customized by the teacher.

The game board presents buttons to confirm results, restart the match and go back to the pre-game listening activity. In all these cases, user performances are saved in a database where players are identified by their nickname, class and school only, so as to protect their privacy; no personal data nor any other sensitive information are saved in the database.

6 EXPERIMENTATION

The experimentation started in two Italian primary schools in February 2021, in the midst of the resurgence of the COVID-19 pandemic. The schools involved were "Istituto Comprensivo Lucilio", Sessa Aurunca, Caserta, and "Istituto Ancelle della Carità", Palazzolo sull'Oglio, Brescia. The experimental activities started on February 4th at "I.C. Lucilio" and on February 9th at "Istituto Ancelle della Carità".

Even if educational activities started in presence, by the end of the month many schools were forced to switch to remote teaching. This fact necessarily interfered with the experimental plan, which included:

- an introductory lesson where teachers had to explain basic concepts about melody and harmony and show students how to use the platform;
- a pre-test session where the initial level of children has been recorded through in-class games with Songs No. 1, 2, and 3.
- a number of lessons where the games on the platform should have been accompanied by explanations by the teachers and face-to face and physical activities, as described in (Mandanici et al., 2019);
- a final post-test, planned at the end of the fourth week of activity in order to evaluate the advances obtained.

Due to the forced switch to remote teaching, only a part of the pre-test phase could be realized in presence (see Figure 3), while the experimentation – currently under way at distance – will miss all the planned face-to-face activities.

Anyway, *Harmonic Touch* is a Web-based framework, consequently it is able to support different use modes without changing the interaction paradigm, thus reducing the differences that exist between supervised in-class activities, supervised out-of-school activities, and unsupervised home activities.

6.1 Aims

For the purposes of the present paper and in the uncertainty of being able to continue and control the experimentation in a remote teaching situation, we consider pre-test results (obtained during the first lesson in each school) and the data gathered during unsupervised experimentation in a 7-day period after the date of first access.

The analysis concerns three main research questions:

RQ1 the evaluation of user performances for each song;

Figure 3: In-class activities during the pre-test phase.

RQ2 the evaluation of user performances for each harmonic change in relation to the musical characteristics of the song excerpt;

RQ3 the evaluation of the efficacy of the platform in extending school work at home.

RQ1 focuses on both personal and aggregated results achieved by players song by song. Even if this question apparently addresses how well players have performed, the real goal is understanding what principles can drive the choice of song excerpts to be employed both in pre-test and in unsupervised game sessions. Game-play data, gathered for the first time in a field experimentation, can help to unveil the musical characteristics that influence the perception of difficulty. In preparing materials for the second experience, we aprioristically assumed that the perceived degree of difficulty could depend on the following parameters: excerpt duration, number of harmonic changes, average frequency of changes, harmonic complexity, irregularity of the harmonic rhythm. Answering RQ1 implies a better understanding of such mechanisms.

RQ2 focuses, once again, on both personal and aggregated results achieved by players, but, in this case, at a finer level of detail: user performances are assessed on single chord changes. Understanding the origin of poor results requires the analysis of chord models, the regularity in harmonic changes, and the extension of tonal areas. Harmonic changes where children encountered higher difficulties can give some useful hints to steer the didactic action and to set the

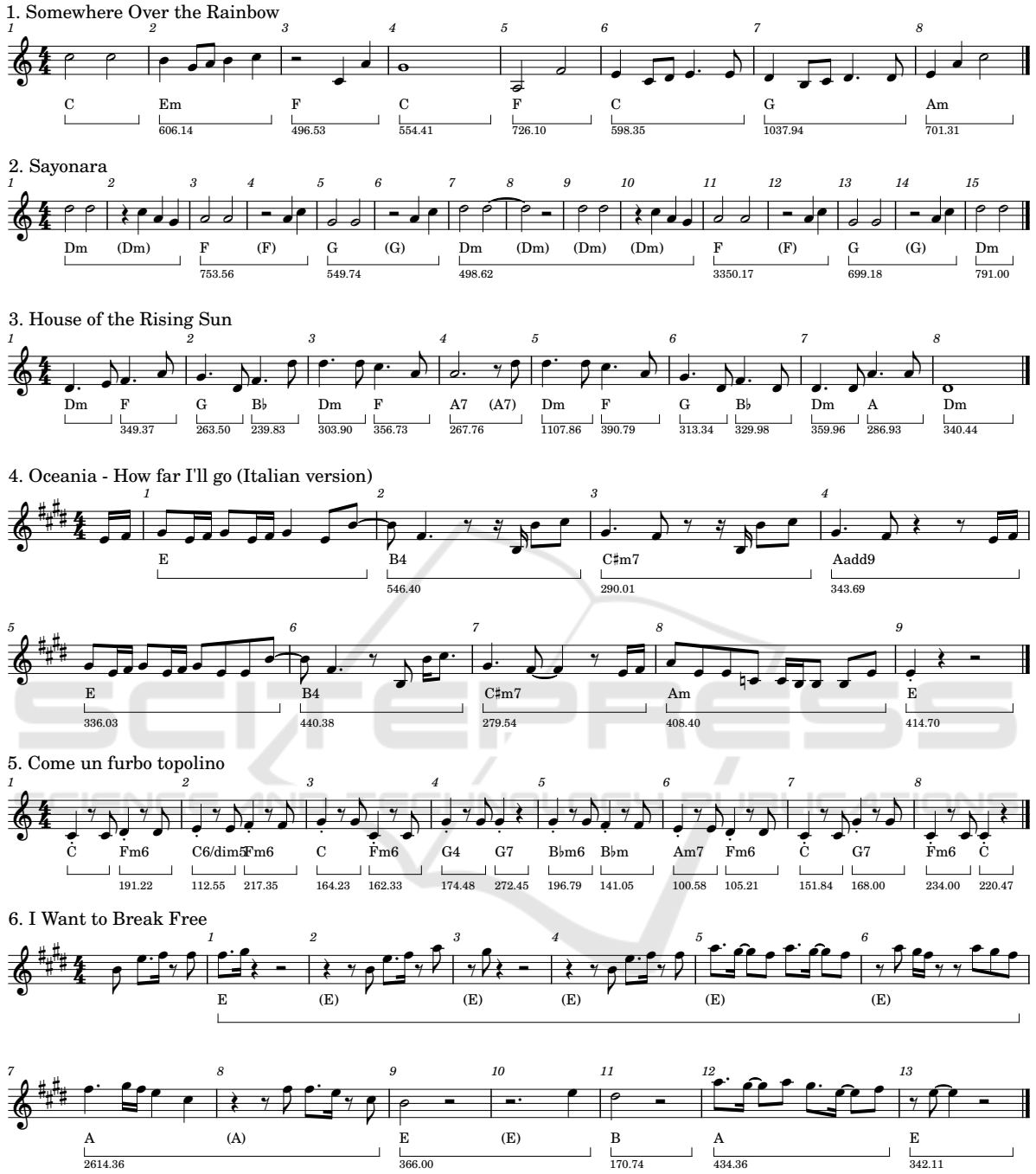

Figure 4: Scores of the songs used in the experimentation. The lines below chord symbols indicate the occurrence of chord changes and the extension of the corresponding harmonic areas. Composite rhythm is expressed by bracketed chord indications. Small numbers below indicate the mean of the absolute values of errors (anticipations and delays) expressed in ms. The first chord has no number associated since it corresponds to the initial play event, so the error is always null.

post-test materials accordingly.

Finally, RQ3 refers to the potential of the platform to extend the school activities also at home. This is a relevant goal in a period where in-presence activities are so discontinuous and uncertain. The platform can play a unifying role between face-to-face teaching and online activities, thus mitigating the inconveniences and the difficulties of the COVID-19 pandemic. In this sense, it is fundamental to measure also the level of engagement, so as to push students

towards personal goals and avoid the sense of frustration due to repeated failures.

6.2 Subjects

The experimentation has involved so far 46 children (29 females) from two Italian primary schools: 21 students (15 females) from "Istituto Comprensivo Lucilio" and 25 students (14 females) from "Istituto Ancelle della Carità". The children of the former school are attending 2 classes of the 4^{th} grade, the students of the latter are attending 2 classes of the 5^{th} grade. Their age is comprised between 8 and 11 years.

The two student populations are comparable concerning age, educational goals, previous music knowledge, etc., so their performances have been evaluated without considering their different origin.

6.3 Materials

Music excerpts have been chosen by teachers based on their educational goals, the characteristics of students, and considerations related to amusement and engagement. The songs selected for the pre-test phase and for the games to be played at home are listed in Table 1: they cover popular music (Songs No. 1, 3 and 6), nursery rhymes (Songs No. 2 and 5) and animation-movie soundtracks (Songs No. 4). Even if children are expected to be already familiar with most of them, a pre-game listening phase is available for each song.[21]

While Songs No. 1, 4, and 5 show a regular pace in harmonic changes, Songs No. 2, 3, and 6 are characterized by different types of irregularities (see Figure 4).

Song No. 2 presents harmonic changes every two bars and at a slow tempo, but introduces a prolonged Dm chord across the phrase that begins at bar 9. Moreover, in the first beat of bar 9 the audio track presents a strong percussive sound, which makes it very difficult for children to resist the temptation to push the button, even if there is no harmonic change.

Song No. 3 is rather regular except for bar 4, where the harmonic rhythm stops for a whole bar on the dominant chord (A7). However this structure does not conflict with the metrical organization of the melody.

Song No. 6 is characterized by a very unusual structure, with a very long tonic chord (E) at the beginning, lasting 6 bars. Then a more regular repetition of 2-bar harmonies (A, E) is followed by bars 11, 12 and 13 each with one harmonic change. Moreover Song No. 6 has the slowest pace of chord changes.

[21]Please note that music pieces can be listened by entering the platform with the anonymous account, choosing Experience No. 2 and selecting them from the complete list.

6.4 User Performances

The assessment of user performances is a non-trivial problem. Which aspects should be measured? What time offset should be tolerated to consider a real-time user action as correct? Is the set of parameters presented in Section 6.1 suitable to describe the perceived level of difficulty of a song? These problems, partially addressed in a pre-experimental phase (Avanzini et al., 2019b), will be re-evaluated in light of experimental results.

Detailed data about user performances are available at http://harmonictouch.lim.di.unimi.it/results/early/lucilio.html for "Istituto Comprensivo Lucilio", and at http://harmonictouch.lim.di.unimi.it/results/early/ancelle.html for "Istituto Ancelle della Carità". In these pages, results are organized user by user. Each diagram represents a game, each trial is one of the attempts made to win in a single game. At the end of such pages, synoptic tables for each song are reported, with detailed information about chord changes: the average error, the variance, the maximum error due to anticipated (highest negative value) and delayed (highest positive value) clicking, the mean of absolute errors, the number of positive errors, the mean of positive errors only, the number of negative errors, and the mean of negative errors only. For the sake of brevity, only the most relevant data will be presented and discussed in the following.

Concerning RQ1, we analyze the data collected in both schools, paying particular attention to the average error obtained during school pre-test and home activities. In order to obtain a single value for each song, the process consisted in calculating the average error measured on all chord changes as detected by the students of both schools (see Figure 5). The underlying idea was to find an aggregate indicator for the level of difficulty experienced by students: absolute values closer to 0 should indicate exercises where the identification of chord changes is simpler; nevertheless, it is worth underlining that the reasons can be heterogeneous.

The piece that reports the highest error is Song No. 2, followed by Song No. 6, while the piece where children performed best is Song No. 5. From the analysis of these results, difficulty does not seem to depend on the number of harmonic changes (Song No. 2 has the lowest value) nor on harmonic complexity (Songs No. 2 and 6 employ the smallest number of harmonies), but, rather, on the average duration of the chords μ (see Table 1).

Table 1: The songs employed in the pre-test and for home activities: d is the duration of the song excerpt in seconds, n_c is the number of harmonic changes, μ is the average duration of chords in seconds, n_h is the number of different harmonies, and r is a Boolean value concerning the regularity of harmonic changes. Other columns are self-explanatory.

phase	song no.	title	year	d	key	n_c	μ	n_h	r
pre-test	1	Over the Rainbow	1990	25.4	C	8	2.82	5	yes
pre-test	2	Sayonara	2009	31.0	Dm	6	4.43	3	no
pre-test	3	House of the Rising Sun	1964	27.2	Dm	13	1.94	5	no
home	4	Oceania	2016	23.7	E	8	2.63	4	yes
home	5	Come un furbo topolino	2009	18.2	C	8	1.14	6	yes
home	6	I Want to Break Free	1984	30.5	E	8	5.08	3	no

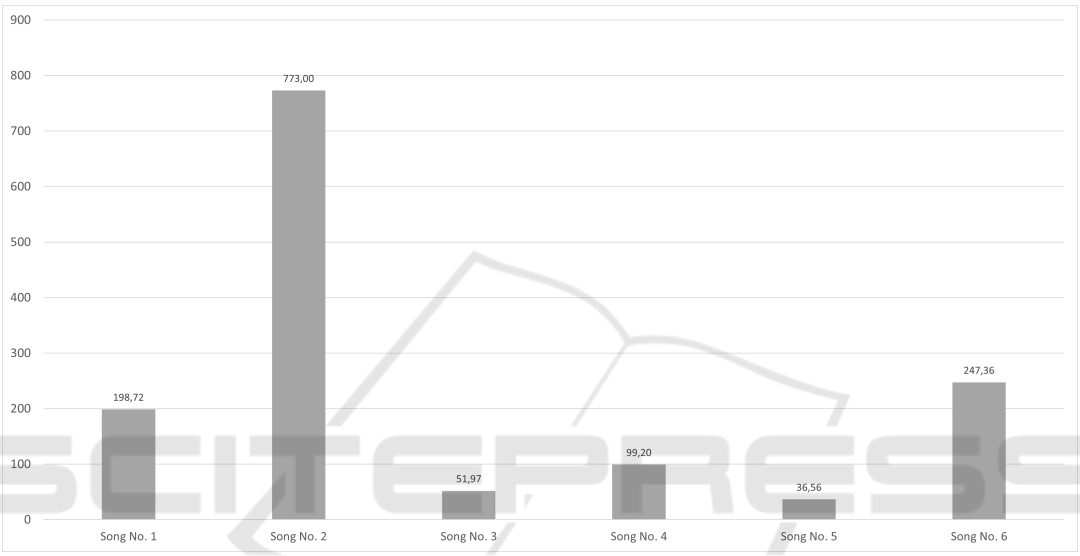

Figure 5: Mean of the (absolute) errors on chord changes measured song by song. The tallest bar is associated with the hardest exercise (Song No. 2), the shortest one with the easiest exercise (Song No. 5).

Songs No. 2 and 6 present the largest average durations μ. Surprisingly, Song No. 3, whose number of harmonic changes is significantly higher than the other songs, obtains the second best score with an error of 51.97 ms. Song No. 3 has also an irregularity in the harmonic rhythm at bar 4, where the A7 chord stops for 2 beats; but, in this case, there is no conflict with the metrical organization of the melody. Anyway, the next change after the irregularity – occurring at bar 5 – obtains the maximum error of the whole song: 1107.86 ms.

On the other hand Song No. 5 – although characterized by a regular harmonic rhythm – has the highest level of harmonic complexity and the smallest average chord duration (μ =1.14 s). Evidently the regularity combined with the high speed of change plays a decisive role in the perception harmonic accents.

In order to answer RQ2, we analyze the occurrence of the harmonic changes in Songs No. 2 and 6 where children collected the most relevant errors. For Song No. 2, the highest error is at the 4$^{\text{th}}$ harmonic change, equal to 3350.17 ms (see Figure 4). This is due to the effect of the superposition of harmonic rhythm (4 bars of Dm from bar 7 to 10) with the metric accent of bar 9. For Song No. 6, the most relevant error, equal to 2614.36 ms, occurs at the 1st harmonic change. This is due to the confusing effect of the very long tonic chord (6 bars of E from bar 1 to 6) which makes it hard for children to locate the next change at bar 7.

RQ3 can be addressed by comparing the number of games played during the pre-test sessions and the games played at home in the 7 days after the pre-test. We have limited our investigation to one week since it was the shortest interval before the following lesson. The pre-test is also the lesson when children experienced the first access to the platform, while, from the afternoon onward, they were free to play whenever they wanted.

Table 2 shows the statistics of the games played during the pre-test and at home. Although there is a remarkable difference between the two schools in the number of users who autonomously accessed the platform at home, it is interesting to note that the overall

percentage of games played at home is not less than 64% of those played in the pre-test. The percentage of successful games is much better at home than at school for the students of 'Istituto Comprensivo Lucilio" (2% at school, 12% at home), while it is nearly the same for the students of "Istituto Ancelle della Carità" (15% at school, 14% at home). These results seem to indicate that the game has greatly engaged children, encouraging some of them to play even outside school hours. The gamification approach has pushed them to experiment autonomously, in some cases obtaining much better performances.

7 DISCUSSION

While experimental activities are still running and in the uncertainty of its progress, we can only guess what the trends will be once the experimentation is complete. However, from these early results, we can assume that the real difficulty in the detection of harmonic changes is mainly connected to the average duration of the chords μ, or equivalently to the speed of changes.

In the choice of the materials for the pre-test we tried to avoid songs with frequent harmonic changes, considered too challenging for children. Unexpectedly, slow changes seem to be more problematic, mainly when they conflict with the metrical structure of the melody, as it happens in Song No. 2.

Also irregularities in the changes and in the harmonic structure do not seem to have a deep impact on success rate. Actually, looking at the errors of Song No. 6, there is a peak in the first change, but offsets dramatically decrease as soon as the song takes a more regular trend. Song No. 3, even if marked with a (low) level of irregularity, obtains a good score and performs better than regular songs such as No. 1 and 4.

On the other hand the successes recorded for Song No. 5 – with a speed of harmonic changes approaching the second – suggest that the timing is a critical point for deciding the levels of difficulty for the exercises of this second experience of *Harmonic Touch*.

Table 2: User performances collected during in-class pre-test and home activities.

	Lucilio		Ancelle	
	pre-test	home	pre-test	home
Users	22	7	19	14
Games	92	59	488	384
Won	2	9	59	55
Lost	90	50	429	329

The trend that emerges is that a problematic issue is the inability to predict the occurrence of harmonic changes when distant in time. This prolonged standby seems to leave the listener without reference points, causing errors as soon as the next harmonic change occurs. Consequently, most teaching efforts in the 4 weeks of experimentation before the post-test should address the sensitization of the various cases of composite harmonic rhythm, mainly when it contrasts with the metrical structure of the song. This goal can be achieved through user-tailored exercises, listening activities, and games on songs with characteristics similar to those proposed in the pre-test. Also physical games with different groups of children or different parts of the body marking metrical and harmonic accents could help, but these activities are clearly hampered by the current pandemic emergency.

Finally, data about the use of the platform are very encouraging. Soon after enabling user accounts, some students began to play independently outside of class hours, as revealed by the timestamps of game sessions recorded in the database. Another encouraging aspect is the request made by children to increase the song dataset available. These facts bode well for the continuation of educational activities even at distance, and they are an indicator of the engagement level. At the moment we are unable to predict if the accesses outside school time will increase or decrease as the experimentation proceeds, also because teaching at distance breaks the traditional division between school hours and extracurricular activities. Actually, what is emerging is a new learning structure where face-to-face activities are increasingly mediated by virtual learning environments. This allows not only the overcoming of the traditional organization of time and space dedicated to educational activities, but changes their inner nature, helping to design new organizational models and educational practices.

8 CONCLUSION AND FURTHER WORK

In this paper we have presented one of the components of the *Harmonic Touch* platform, whose general goal is to raise awareness about tonal harmony in young students through a gamification approach. The tool under exam is an experience to help users to detect harmonic changes in songs, namely the occurrence of new chords. The interface has been designed as a treasure map, with a number of steps (corresponding to new chords) to complete at the right time (corresponding to harmonic changes in audio) in order to reach the final goal. We have presented and dis-

cussed the early results gathered with primary school students aged 8 to 11 and coming from 4 classes of 2 Italian institutes.

Regarding future works, there are multiple directions to take. The first one concerns the extension of experimental activities to a wider audience of users, potentially presenting different characteristics in terms of age, school grade, geographic origin, previous musical experience and skills, and so on. Other school teachers interested in the project have already been contacted, and only the uncertainty due to the COVID-19 pandemic has stopped the launch of a larger-scale experimentation. Gathering more data is expected to make more statistically significant trends emerge.

Other considerations about the suitability of the platform for distant education are likely to emerge in the near future. In fact, so far the platform has been used either in class, under the direct supervision of teachers, or at home, in a relaxed out-of-school environment. A third way is not only possible, but also probable: a new lockdown for Italian schools could foster the adoption of the platform for remote and synchronous school activities. In this case, it will be interesting to analyze student performances and compare them to the previously mentioned scenarios.

Another direction for future work concerns platform design and implementation. Field trials highlighted a number of minor bugs, promptly exploited by smarter students to artificially improve their results. In this sense, our beta testers demonstrated to be very motivated to cheat the system. An example was the extremely quick repetition of mouse clicks over the current change in order to get additional score points, an effect obtained by exploiting the very narrow tolerance window introduced to manage clicks not perfectly timed. This bug was solved as soon as it was detected by reading data; anyway, it did not invalidate performance analysis since we did not base our considerations on score points, which are presented in the interface only to improve motivation. Concerning the latter aspect, in a future release we are planning to further enhance gamification aspects, e.g. by introducing hall-of-fame and leaderboard functions in order to increase user's engagement. One interesting remark that came from one teacher is that, in the absence of such features, students started to share their scores by taking pictures of their game results and sending them to the class chat.

An aspect to further investigate concerns the evolution of the engagement level when students, on one side, get accustomed to the game play, and, on the other side, have to face harder exercises. The data collected so far do not allow to make inferences about the long-term trend and understand to what extent student engagement is due to the novelty of the platform rather than the idea itself.

From the educators' perspective, the availability of a web tool to support music-education activities has been appreciated by the teachers who decided to take part into this initiative. Anyway, being an early experimentation that involved 4 classes only, we cannot make general statements about teacher's acceptance and level of satisfaction. This aspect will be further investigated in future experimentation, that is planned to involve a much higher number of schools and classes.

The song dataset, currently constituted by 44 pieces, will be further extended and customized thanks to the contribution of educators, based on their educational goals. New pieces can be prepared offline by teachers, but, at present, they can be added to the platform only by system administrators. The working group is also planning to implement back-end tools to let teachers upload their materials independently.

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