THE RHYTHMIC DICTATOR: DOES GAMIFICATION OF RHYTHM DICTATION EXERCISES HELP?

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ABSTRACT

We present the development and evaluation of a gamified rhythmic dictation application for music theory learning. The application's focus is on mobile accessibility and user experience, so it includes intuitive controls for input of rhythmic exercises, a responsive user interface, several gamification elements and a flexible exercise generator. We evaluated the rhythmic dictation application with conservatory-level music theory students through A/B testing, to assess their engagement and performance. The results show a significant impact of the application on the students' exam scores.

1. INTRODUCTION

Music theory learning and ear training is not very popular among students in music education and informal music learning, although knowing about music theory stimulates knowledge about music and enhances music appreciation. Considering the expansion of e-learning, an overwhelming part of the music theory learning still takes place in the traditional paper-and-pen form. Opportunities therefore exist for increasing student engagement with appropriate information and communications technology (ICT) tools that would support the learning process while motivating the students to use them through the use of gamification elements.

Games and gamified applications have gained traction in recent years and have become important tools in the ICT and e-learning communities. The evaluation of gamification [1, 2] and student engagement [3] has received significant attention, and the development of specialised platforms and apps for e-learning has flourished [4, 5]. Gamification has often been a medium for information retrieval and collaborative data gathering [6]. In music information retrieval, several approaches for gamification of music annotation and meta-data gathering have been proposed. Kim et al. [7] proposed the Moodswings game for mood labelling, where the users were asked to plot the mood on the valence-arousal graph. They collected over 50.000 valence-arousal point-labels on more than 1000 songs. The authors identified gamification as the key component of user engagement. In a similar manner, Mandel and Ellis [8] proposed a web-based game for collecting song meta-data, such as genre and instrumentation. Law et al. [9] created the TagATune game for music and sound annotation. The game collects comparative information about sounds and music, where users play the game in pairs. The authors collected responses from 54 test users. They also focused on the user engagement through three aspects: sense of competence for the user, pleasantness and sensory user experience, and the opportunity to connect with a partner. Burgoyne et al. [8] presented a game named Hooked to explore the "catchiness" of songs on the responses provided by 26 users. The dataset consisted of 32 songs. Aljanaki et al. [10] developed a 'game with a purpose' to gather emotion responses to music. They collected more than 15,000 responses from 1,595 participants. Overall, in the MIR community, the developed applications mainly served as a medium to gather data.

On the other side, many web and mobile platforms for music learning exist, that also incorporate gamification elements, from instrument-related applications (e.g. My Piano Assistant [1], Yousician [2]) and music accompaniment software (e.g. iReal Pro [3]) to music-theory platforms (e.g. theoria.com, musictheory.net, Musition [4]). These platforms, however are commercial and closed-source, they are not extensible to new topics (by teachers) or adjustable to individual learning groups and curricula. While there is no doubt that they can help the user to improve their knowledge and performance, the lack of adjustment to in-class use within existing curricula is difficult without code-level access. Access to such commercial platforms may also not be affordable for all parties (e.g. public music schools).

In the paper, we present the Rhythmic dictator: a rhythmic dictation application, which is part of our larger effort to gamify various aspects of music theory learning into a common open-source platform. It is implemented as a

[1] Available on Google Play and Apple App store
[2] https://yousician.com
[3] https://irealpro.com/
[4] https://www.risingsoftware.com/musition

web-based application with a responsive user interface that is specifically designed for mobile devices, since these are the most commonly used by students. The application automatically generates exercises according to the student's level of knowledge and in-app progress. To increase student engagement, gamification elements, including badges and leaderboards are implemented.

We analyse two aspects of the application's in-class use with first and second year conservatory-level students: the students' engagement, and the application's impact on the students' performance.

2. THE RHYTHMIC DICTATOR

Three exercise types are commonly performed by music theory students: melodic (interval) dictation exercises, rhythmic dictation exercises, and harmony exercises. Conventional practice usually consists of listening to a pre-recorded or teacher-performed dictation and solving it on paper. Evaluation and grading is done by the teacher.

Our rhythmic dictation application (the Rhythmic dictator) offers an easy to use and automated way for students to solve rhythmic dictation exercises in-class and out-of-class with immediate feedback on their performance and a customizable exercise generator which adapts the difficulty of generated exercises to the student's level of knowledge. The application was developed as a responsive web application, which adapts well to mobile devices. In this way, the development and maintenance of the platform is simplified, as the platform is browser-accessible on all major platforms—Windows, Linux, OS X for desktop environments, as well as Android and iOS for mobile devices.

The application is incorporated into the Troubadour platform [5], which is a framework for music theory learning with support for gamification elements including badges, points and leaderboards. The application and the platform are easily deployable with the use of package management tools, and the code is available as open source software and publicly accessible on GitHub [6].

2.1 The user interface

In rhythmic dictation, the students listen to a rhythmic sequence, which they have to write down in music notation. The main part of the Rhythmic dictator's user interface (Figure 1) therefore includes two staves displaying the input rhythmic sequence and a rhythm input interface. The upper (smaller) stave shows the entire sequence with a red rectangle indicating the area shown in the lower larger stave, where the user inputs their response to the dictation. The dictation can be played-back repeatedly and paused while playing.

The rhythm input keyboard supports a variety of rhythmic inputs: note and pause lengths, subdivisions and syncopation. To accommodate for the small screens of mobile devices, the inputs are split into two layouts: on the primary layout, the most common note and pause lengths are displayed. With keys for subdivision and syncopation, the layout changes to show a set of additional input options, as shown in Figure 2.

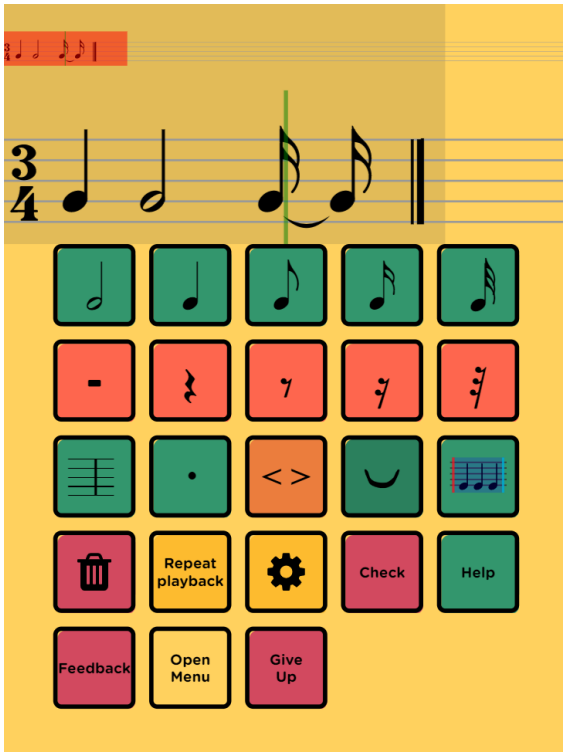


Figure 1: The main screen of the rhythm dictation application on a mobile device. The primary rhythm input interface is shown below the staves.

Each exercise begins with a metronome indicating the meter and is followed by the rhythmic dictation playback. The student can pause and replay the dictation, and adjust the playback speed and volume. The dictation is played using an organ sound. The sound was chosen in discussion with music theory teachers due to its fast onset, steady sustain and a clear offset. While the sound of piano is commonly used for melodic dictation, its unclear offset can cause ambiguities in determining the event length (vs. pause). Our choice of the sound was also evaluated with the users during the evaluation period.

2.2 Automatic generation of exercises

The Rhythmic dictator includes an exercise generator that can generate exercises of different difficulty levels. The difficulty of a rhythmic exercise is governed by several parameters: subdivision complexity (from quarter notes, to 32nd notes), subdivision types (dual vs. ternary), subdivision distributions, and the number of events (length of the sequence). Randomly generating the exercises with uniform distributions of these parameters yields meaningless and unrealistic sequences that are non-intuitive and difficult to solve and which lower the student's motivation. We therefore analyzed the existing materials that teachers used

[5] https://trubadur.si

[6] https://bitbucket.org/ul-fri-lgm/troubadour_production

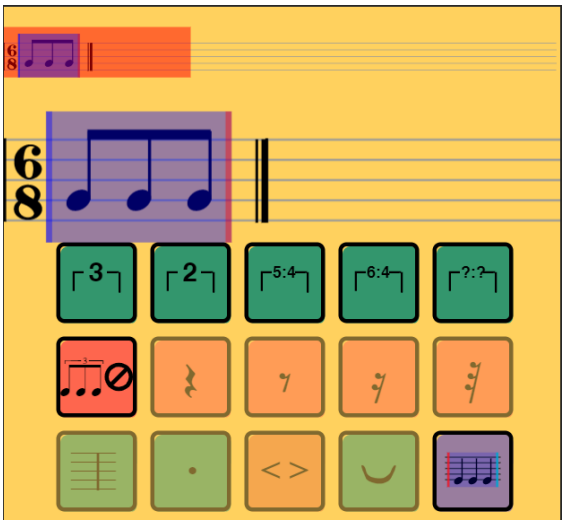


Figure 2: The secondary keyboard layout with options for adding and modifying subdivisions.

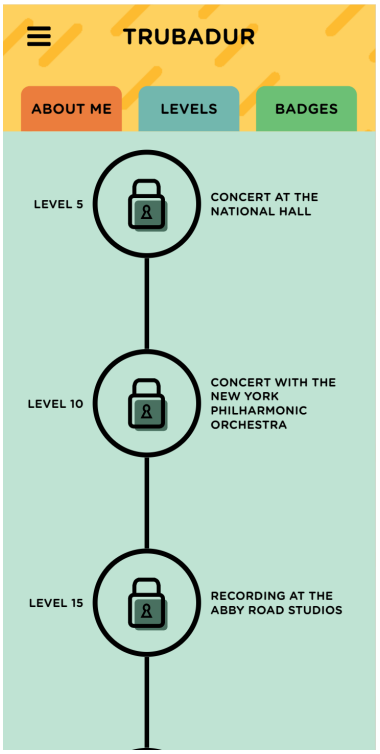
in their classes and created parameter distributions for various difficulty levels. The distributions take into account the frequency of event occurrences, as well as their in-bar position, to reflect the rhythmic patterns, which are common in music. In this way, the randomly generated sequences become more musically meaningful and engage the student individually with sufficient difficulty, while not overwhelming them with either too difficult or meaningless examples.

We arranged the distributions into 16 difficulty levels, ranging from elementary music school to academia. The levels are split into four major levels, and each major level is split into additional four minor levels. We marked the levels with numbers {11-14, 21-24, 31-34 and 41-44}, with the first digit corresponding to the major and the second to the minor difficulty level. The parameter distributions for each level were set as the default values for exercise generation in the rhythmic dictation application, however teachers are able to modify the distributions according to their didactic expertise and needs.

2.3 Gamification elements

To increase the motivation for using the application among the students, we enriched it with elements of gamification. We use three gamified elements related to students' performance: progression between multiple levels of proficiency, a leaderboard and achievement badges. The gamification elements are visible on the home screen, where students can browse through their achievements, as seen in Figures 3a and 3b.

While using the application, students earn points by solving the exercises, which directly affects their achievements. Each exercise consists of two sequences that can be answered multiple times. After each completed exercise, the student's points are calculated, measured as a function of several factors: exercise difficulty (across the 16 difficulty levels), time taken (in minutes), number of corrections (additions and deletions of notes), the use of the metronome (yes/no), the number of submission attempts (checks for correctness), and whether the final sequence was correct. The sum of points can be either positive or negative.



(a) Gamification levels

(b) Achieved badges

Figure 3: Gamification elements. The left screen shows progression between multiple badge levels of proficiency, while the right screen shows the badges obtained during the practice.

By solving more excercises and progressing through levels of difficulty, students increase their level of proficiency (Figure 3a). The levels were defined by the teachers, and vary from local orchestra, to different competitions and international institutions.

The badges, shown in Figure 3b, reflect three different aspects of student progress. The first aspect is accuracy: completing an exercise with(out) a certain amount of mistakes (from 50% up to 100% correct answers). The second aspect is the continuity of the student's engagement with the platform: playing an exercise for a certain amount of days in a row—3 days, 5 days, a week, two weeks, a month. The third aspect is the student's speed: the amount of time needed to complete an exercise in 5 minute intervals, ranging from 25 minutes to 5 minutes.

As an additional element of gamification, we implemented a leaderboard. The leaderboard shows the cumulative points collected by an individual. More points can be achieved by both the number of solved exercises and the exercise difficulty. The students can observe their performance and compare it to the other players. By clicking on one of the platform's users the selected user's profile page is displayed, with their achieved levels and badges.

3. EXPERIMENT

The primary goal of the developed application was to provide an open platform, which would engage students and increase their performance in rhythmic dictation tasks. The application was tailored to increase student engagement through gamification elements and an intuitive interface on mobile devices. In our experiment, we wanted to assess whether these goals were achieved.

We evaluated several hypotheses. First, we assumed the mobile-friendly interface will enable the students to engage with the application. While the students might spend more time with an individual exercise at the beginning to get used to the interface, the time spent for solving an exercise should in time decrease due to familiarity with the interface and the student's increased proficiency. Second we hypothesized that student engagement will have an impact on their exam performance.

During the experiment, we collaborated with first and second year students at the Conservatory of Music and Ballet Ljubljana, Slovenia. First, we developed the application through continuous evaluation with four conservatory students (two first and two second year), who represented a sample of our target audience. We continually evaluated the students' interaction with the application: whether they understood the user interface, whether the exercises were appropriately demanding and whether the exercises were sufficiently interesting and engaging.

We then evaluated the application with the first and second year students at the conservatory. The students were randomly divided into one test and one control group in each year. The evaluation lasted for five weeks, during which we held four in-class meetings with the students of the test groups. Students were asked to use the application during the meetings through a group student challenge, during which the students competed to achieve points in the application.

After the five week period, students of both test and control groups participated in a standard curriculum exam. We compared the exam results and observed the application's impact on exam performance. The test groups consisted of 11 first and 12 second year students, while the control groups consisted of 11 first and 13 second year students.

In this section, we first describe the evaluation, followed by an analysis of the collected data.

3.1 Application evaluation - student challenge

During the five-week application evaluation period, four meetings with the test group students were organised. The meetings were held during the music theory classes. Our goal was to observe the student engagement with the application. To gain the interest of students, we proposed a student challenge, where the students competed to gain points and rank high on the leaderboard.

3.1.1 Initial questionnaire

At the first meeting, the students of both control and test groups were given a questionnaire that contained general questions about the use of tools for practicing music theory on mobile devices. The first part of the questionnaire involved questions about which applications (including music theory apps) the students use on their mobile devices. The second part of the questionnaire consisted of questions about the students' rhythm practicing at home.The questionnaire was answered by 47 students.

All students were using mobile applications, such as social, messaging and music apps (SnapChat, Instagram, FB Messenger, YouTube). 79% of the students reported on using mobile apps for learning new skills, such as foreign languages and instruments. However, applications for practicing music theory, such as Teoria.com, TonedEar and MyEarTrainer, were rarely mentioned. Only a few students (17%) used various rhythmic dictation exercises. In the second part of the questionnaire, most students reported practicing rhythmic exercises at home (67%), however they showed mixed opinions on whether they wanted additional ways to exercise rhythmic dictation, as 55% of students did not want additional rhythmic dictation exercises. The shift in their opinion therefore posed a key challenge for the success of the proposed application.

3.1.2 Weeks 2 and 3

During weeks 2 and 3, we enabled access to the application to the test groups. We conducted a live challenge during a music theory class. The goal of the challenge was to increase student engagement with the application, by enticing them to gather points and rank high on the leaderboard. During the challenge, we motivated the students further by presenting intermediate results live on a classroom display. Symbolic rewards were given to the first three students.

During the week 3 meeting, we also distributed questionnaires to the test group students. We asked the students about their experience with the application. The results of

the questionnaire were mostly positive. When asked if the application was difficult to use, all students answered no (100%). Most of them answered that the exercises were not difficult (16 students, 69%) and that they got used to the application's use over time (16 students, 69%). The answers were consistent with the goal that the application should be easy to use. Most students responded that the rhythm input keyboard worked as intended (13 students, 72%). The majority did not use additional paper and pencil (17 students, 94%) exercises. However, the sound of the organ used by the application was perceived as disturbing (16 students, 89%). Many answered that they would rather listen to the piano because they are more accustomed to it. Two thirds of the students had enough time to complete the exercises (12 students, 67%), and did not adjust the speed of the dictation playback (67%).

3.1.3 Week 5

Five weeks after the beginning of the application's evaluation period, we organised the fourth meeting. We presented the final results of the participating students and handed out plaques to the winners of the challenge. All students received symbolic rewards in gratitude.

We also asked the test group students to respond again to the questionnaire which was handed out during the third meeting. We investigated the changes in their opinions after one month of application use. Again, we received positive responses. The students replied that the exercises were not difficult (91%). All students got used to the application during this time. To most students, the rhythm input keyboard functionality seemed logical and worked as intended (82%). All students began using the application to practice and stopped using the conventional paper and pencil practice. The students also grew accustomed to to the sound of the organ used for playback (73 percent).

Most students had enough time to complete the exercises (91%), and did not adjust the playback speed (91%). When asked whether they showed the application to their friends, the majority responded positively (73%). In their final remarks, the students highlighted the following features:

- the students liked the ability of using the application on a personal computer in addition to the mobile device,
- the scoring and achievements (badges) were motivating,
- the ability to pause/stop the playback was helpful.

3.2 Analyzing the application data

Twenty-three students, 11 from the first and 12 from the second year, completed 496 exercises in total. Each exercise consisted of two rhythmic sequences that could be answered multiple times. In total, the students answered 837 sequences correctly. The first-year students averaged 24.5 sequences and the second-year 26 sequences.

The rhythm dictation application is organised into 16 difficulty levels. In order to advance to a higher level, the student had to complete at least 12 exercises at the current level. When starting the application, the student could choose which level to start at from the subset of levels they already achieved. 39% of the students remained at the first level (level 11), because they did not complete enough exercises to pass on to the next level, while others moved to higher levels. During the evaluation, only one student reached all the rhythmic levels available.We also observed the time needed to complete the individual exercises. In their first exercises, the students needed more time than in later repetitions - the average time gradually decreased with the number of exercises played. With increasing difficulty levels, we noticed that the number of event deletions increased. The number of dictation plays remained steady across all levels of difficulty. The number of attempts to solve also remained steady with the exception of level 11 (1/16 difficulty level), where sequences were trivial for the conservatory-level students to solve.

The gathered data confirmed our assumption that some of the observed values, such as time spent, decreased over time, while others remained steady due to the increasing difficulty of exercises. Student engagement in out-of-class use gradually increased, which we consider a success in terms of user experience - student liked the interface and found it easy to use - as well as gamification elements, which, through the student challenge, brought competitiveness into interaction between students.

3.3 Exam performance

At the end of the evaluation period, the students completed an exam as part of their standard curriculum. The exam was taken in the traditional form, with the teacher dictating the rhythmic sequences and students writing their responses on paper. We analyzed the exam results and compared the grades within and between the groups. The exam was evaluated with grades 1 (worst grade) to 5 (best grade). The first-year control group students achieved an average grade of 4.3, while the test group students achieved an average of 4.5 (4% increase). The results were statistically tested using the MannWhitney U-test and the difference was not statistically significant ($U=16$, $p > 0.05$). A larger difference was observed for second-year students, where the control group achieved an average score of 3.58 and the test group 4.44 (19% better, significant difference, $U=24$, $p<0.001$). As better results were achieved by students using the rhythmic dictation application, we can conclude that the use of the application had a positive effect on their performance in the exam. As both groups were relatively small, we also used a resampling method to compare the group averages. At 1000 replicates, the method estimated a 69.2% probability that the average test group score was greater than the average control group score for the first-year student groups. For second-year results, the algorithm estimated this probability at 99.6% at 1,000 iterations. These estimates confirmed the Mann-Whitney U test, therefore showing that students who used the application performed better in the exam.

The difference between the first (no significant impact)

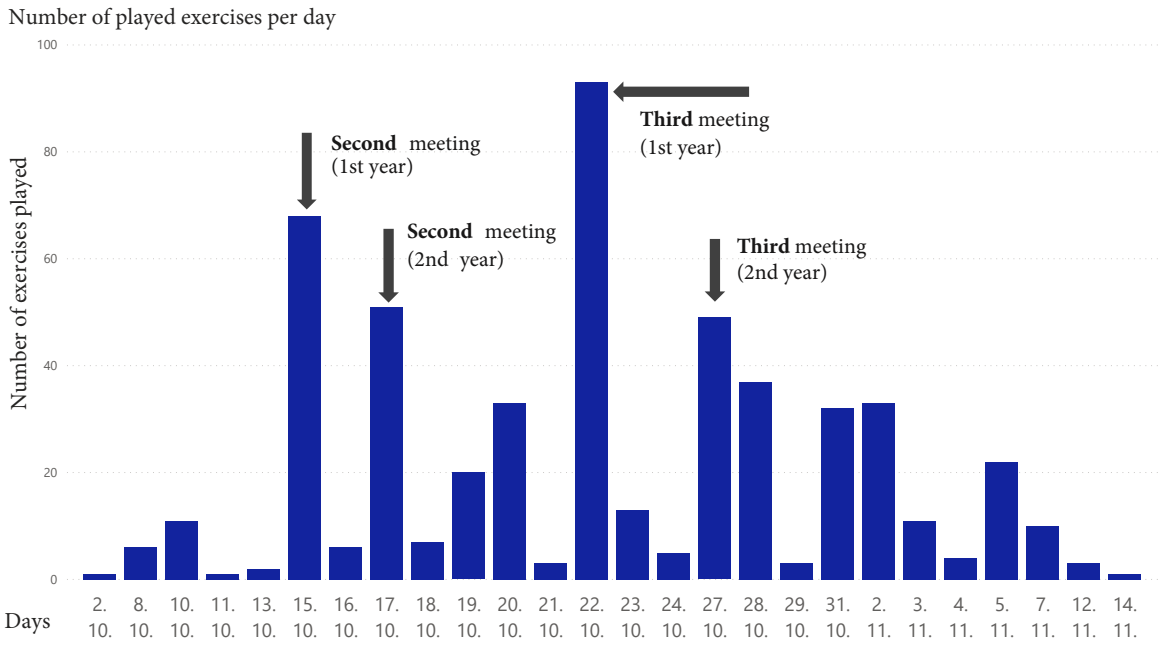


Figure 4: Graph of the application's usage frequency per day. The second and third meetings are marked individually for each test group. The engagement (# of exercises) was initially higher for the first year students, however, it decreased over time, while the engagement for the second year student group remained steady.

and second year (significant impact) students could be attributed to the fact that the second year students were on average more steadily engaged during the application's evaluation period (Figure 4). The students who ranked highest in the competition rankings were from the second year test group. However, both groups were small and a larger longitudinal study is needed to further confirm the results of this evaluation, and to fully evaluate the application's impact on the learning process and performance.

4. CONCLUSION AND FUTURE WORK

In this paper, we presented the Rhythmic dictator—a rhythmic dictation application. The application features a mobile-friendly user interface supported by gamification elements for attaining student engagement, while offering a flexible environment for the teachers. We investigated two aspects of the application—student engagement and exam performance. To engage students, we created a five week challenge during which the students were asked to use the application through a gamified experience of collecting points and badges, which were visible to other students. Their performance was later tested in a conventional exam, where we compared the results of the students who used and who did not use the application.

The evaluation showed that students support the use of a gamified application. Overall, the students reported a very positive user experience, which was further substantiated by the claim that they would recommend the application to their friends.

The comparison of exam results between the control and the test groups showed a positive impact of the application's use on exam results, which was statistically significant for second year students. Although the test and control groups were small and the results should not be too quickly generalised, the study was carried out at the Conservatory of music and ballet, Ljubljana, Slovenia, which represents roughly 50% of the state-wide student population enrolled in a music programme at this level. Based on the evaluation presented in this paper, we can corroborate the gamified Rhythmic dictator application aids the students' performance, which we attribute to gamification and automatization of rhythmic dictation exercises.

To further confirm the application's impact on music theory learning, our current work includes a longitudinal study with new exercise types and an evaluation of the use of the multi-player mode for real-time remote interaction. The application is currently also used in class, where we are collecting new student engagement data.

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