OPTIMIZING THE INTERACTION BETWEEN A SELF-LEARNING GUITAR STUDENT AND A SOUND RECOGNITION BASED EDUCATIONAL GAME

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ABSTRACT

Recently, the Republic of Estonia introduced compulsory guitar lessons to its national upper secondary school curriculum, where all students have to learn the basic chords during their regular music classes. As most pupils do not have a guitar at home, all the practicing has to take place within the classes. Since music lessons take place only once a week, making the most out of the 45 minute group lesson becomes a top priority. In this paper we report the results of building and testing two gamified e-learning applications that utilize machine learning based sound recognition algorithms: (1) interactive flash cards and (2) an arcade game, that both aim to facilitate drilling the basic chord shapes on the guitar and have different levels of interactivity. We compared the gain of the chord changing speed under the two interactive conditions during a single music lesson using a two group pre/post-test design (N=61). Backed by the cognitive theory of multimedia learning, we hypothesized that the group that practices under the less interactive conditions will demonstrate better results. We had to abandon the hypothesis as we were unable to detect any significant differences between the learning results of the two groups.

Keywords: gamification, online music education, music education technology, automatic feedback, sound recognition, guitar, group lessons.

BACKGROUND

Estonian national curriculum for upper secondary schools (2011, 2014) demands that, between grades 7 and 9, every student has to learn the basic guitar chords. This is a fairly new addition to the program and has raised several practical questions. First, the teaching is done by school music teachers who have limited experience with guitar. Secondly, the teaching has to take place with 24 students simultaneously i.e. in group lessons. Thirdly, not all students having a guitar at home makes giving homework impossible. To alleviate the lack of relevant didactic material for group lessons, a dedicated method book was written by one of the authors of this paper (Käo, 2011), which became the basis for teacher training courses organized by the Estonian Academy of Music and Theatre. The problem of homework however still remained.

Whether in medicine, chess, sports or music, obtaining expert skills takes thousands of hours of deliberate practice (Ericsson, Prietula, Cokelyo, 2007). Even without the ultimate goal of becoming an expert on a musical instrument, there is really no substitution to a certain amount of repetition (Lehmann, Gruber, 2006). Since practicing at home is impossible for many students, the main question is how to get 11-16 year old students to practice effectively in the classroom in the group lesson context for the entirety of 45 minutes.

This is clearly no easy task. When investigating the practicing habits of 11-12 year old pupils, Austin and Berg (2006) found positive correlation between the motivation and the amount of practice. Steve Oare (2012), after observing the practicing process of 7-9 grade children, concluded that their practice goals and the criteria of success tended to be unclear. He also noticed that the students who had a more defined goal were able to keep their focus on practicing for longer periods (up to 12 minutes).

GAMIFICATION

Clear objectives, short-term achievable goals, and fostering engagement are the keywords that practicing research shares with the gamification literature (e.g. Deterding et al. 2011; Lee, Hammer, 2011; Muntean, 2011; de-Marcos et al., 2014). Sadly, the gamification research in music education has not yet come to the point where we could say much about its effects. Generally, gamification is expected to aid learning processes at the school level (Lee, Hammer, 2011), at the classroom level (de Freitas, de Freitas, 2013), at personal level (Betts, 2011), and as a connection between formal and informal education (Cassidy, Paisley, 2013). Despite the scarcity of educational research on music games, several games exist and some of them have enjoyed great popularity and are reported to raise student engagement (Cassidy, Paisley, 2013; Reyher, 2014). In addition to the commercial music games that are capable of providing automatic feedback there are several experimental technological tools being built and tested (e.g. Käo, Niitsoo, 2014; Nijs, Leman, 2014).

FEEDBACK AND INTERACTIVITY

In most cases the feedback provided by a music learning application is presented mainly visually on the screen (e.g. Hoppe, Sadakata, Desain, 2006; Wilson et al., 2008). This makes sense, as the audio channel is usually already saturated by the student's own practicing. Thus using the visual channel is in line with cognitive theory of multimedia learning (CTML) (Mayer, 2001; Mayer, Moreno, 2010) which argues for using multiple modalities simultaneously. However, there are more rules to be considered when optimizing the cognitive load of a study material. A number of researchers have detected that higher levels of interactivity can increase cognitive load (see Homer, Plass, 2014). When proposing a definition for interactivity, Koolstra and Bos (2009) list the following features to look for: synchronicity, timing flexibility, control over content, additional participants, use of sight, hearing and other senses. Most of these features are present in games, making them one of the most interactive ways to learn. However, we cannot conclude that high cognitive load makes games ineffective learning tools, as there are works which suggest that higher interactivity does not necessarily result in worse learning. Instead, it may promote transfer (Homer, Plass, 2014) and raise motivation (Zimmermann, 2012). In addition, the potential negative effects caused by poor instructional design may sometimes be simply too small compared to the magnitude of positive effect of the overall learning experience. This explanation was proposed by Liu et al. (2012) who could not confirm the split-attention effect (Sweller, 2010) in a learning situation, where information was coming from both virtual and physical sources.

AIM

Drawing from this background it seems likely that the described issues of teaching musical instruments in a school classroom setting - the need for physical repetition, and the lack of clear objectives and short-term achievable goals - could be addressed with gamified tools. At the same time, one of the essential features of any game, the high level of interactivity, could potentially have negative effects on learning due to high cognitive load. To find out if such negative effect is detectable, we designed two different gamified learning applications, that mainly differ in the level of interactivity, and ran a two-group trial.

METHOD

Participants were upper secondary school students (N' = 104) from 3 public schools in three cities of Estonian Republic who have compulsory guitar in their curriculum. However, due to technical difficulties with microphones and computers as well as very low changing speeds (defined as having a median in excess of 30 seconds per chord) of some students, usable data with both pre and post-test results with at least 1 minute of practicing in between was gathered from only **N=61** students.

Thankfully, the data shows that other than the selection bias of sorting out the very weakest students (spending over 30 seconds per chord), the students for whom pre and post-test data is available are otherwise statistically very similar to the full set, with chi-square test failing to show any significant difference (even at 10% level) between the distributions of age, how many of them had practiced the guitar at home or even how many problems they perceived with the chord detection software giving false results. All this indicates that the selection was mostly random and mainly caused by faulty hardware setups that didn't give some students enough time to complete the test.

We will report summary statistics for N=61. Ages ranged from 11 to 16 years (M =13.4 y, SD = 1.43), with exactly 51% of the students being female (47% in N'=104). The students were very evenly divided between the two conditions, with 31 in group 1 and 30 in the other. Randomization of students into groups was done automatically, with users being alternatively assigned to the two groups as they were signing in.

TOOLS AND CONDITIONS

A software learning tool that employed audio recognition to detect the chords being played was presented to both groups. The algorithm used was the same as in the commercial game available at www.strumprofessor.com. The software works in the browser (Google Chrome ver 39 was used in test) and detects chords based on standard microphone input using Fourier transform, time-windowing and standard machine learning techniques with linear classifiers for each chord. To accommodate 20-26 students playing simultaneously, contact microphones (normally used for electronic tuners) were used instead of normal microphones as they ignore any leakage from other nearby instruments. Despite the algorithms being learned for standard microphone, recognition accuracy remained very similar.

Practice conditions were different for the two groups. The first group was shown the name of one chord and when the software identified that student had played it correctly, the next chord was displayed and the process repeated itself. The second group had a more gamified version, inspired by the classic arcade game "Space Invaders". In that case, one or more chord names slowly start moving from the top of the screen towards the bottom, and the student has to "destroy" them by playing them on the guitar. This condition introduces extra cognitive load by having numerous moving objects on the screen on a background of a cloudy sky. It also introduces time pressure, as the students have to hit the chords before they hit the bottom of the screen, at which point they lose one of three lives. If all three lives are lost, the level was reset and the student had to start over. Lastly, it also introduced an element of choice, as the student could choose which of the 2-6 visible chords he/she would play next.

Fig. 1-2. Screenshots of the two practicing conditions.

Many elements of gamification were common to both groups. For both, practicing was divided into 7 levels, all of which had a clear short-term objective: either play a set number of chords or practice ("survive") for a set number of seconds. In both conditions, a real-time score for the level was also calculated, with students that played chords quicker getting higher scores. The levels were designed to become increasingly more difficult by starting with the simplest chords Em, G, C, which can all be played with just one left hand finger, then introducing Am (2 fingers) and only later adding the two most difficult chords of the experiment, D7 and D, which both require three fingers. This was designed to make the short-term goals seem achievable, as the difficulty rose very gradually. Both conditions were also interactive as they responded to the student actually playing the correct chord.

Data Collection

Pre/post test methodology was used to measure the effects of practicing. The test used visuals distinct from either of the two practice conditions to avoid confounding effects. The test consisted of a sequence of the chords, which the student had to play in the fixed order given (G, Em, C, Am, D7, G, Am, D, Em, D7, C, D, G, C, D7, Em, Am). These chords were chosen because they are the simplest to learn and are also the first to be introduced in the textbook used in the schools (Käo, 2011). We also introduced a warm-up to the pre test that had the same visuals but only required each chord to be played once. This was meant to get the students comfortable with the experimental setup and with the computer recognizing the chords and indicating they move on.

A printed form was used to ascertain the background of the students and their prior experience with music and guitar, i.e. whether they had practiced at home or attended a music school. The other side of the form contained questions about the accuracy of the software and was meant to be filled out at the end of the lesson. The paper also contained a cheat-sheet with printed diagrams for all 6 of the chords used in the experiment.

Procedure

The experiment took place in the music classroom, with laptops distributed to the students, one per child, with each child also taking a guitar from the classroom wall. After choosing the guitar, students were given a form and the experimenters (the two authors) walked around the classroom attaching microphones to guitars while students filled it out. This was followed by a short introduction to the experiment by one of the authors (Kristo), after which they were left to interact with the software at their own pace, first doing the warm-up, then the pre-test, then training (one of two conditions). 10 minutes before the end of the lesson, the software was triggered to go to the post-test. After that, students were asked to fill out the other side of the form after which they were free to leave.

To pilot the experiment, the described setup was run once on a small class of 10 students at the computer lab of a fourth school. Since that experiment was done on the computers in the lab instead of the laptops, there were a lot of hardware problems, based on which the decision to use standardized laptops in the following experiments was made. Some software problems were also identified and fixed, and one chord with which the chord detector was struggling was removed from the experiment.

Data analysis and results

As many students made very long pauses in the tests for harder chords even after the warmup, median time per chord was chosen as the measurement of skill level as it is robust to such outlier values. A standard linear model was then constructed to predict the post-test result based on the pre-test result, condition, their interaction term and a list of control variables (sex, age and the background questions from the paper form) and an ANOVA was calculated for it.

The data analysis showed no significant difference between the two conditions, with the condition and condition-practice time interaction variables explaining less than a percentage of the variation, thus supporting the null hypothesis that the two conditions did not differ from one another.

If we look at the rate of chords played during practicing, there is also relatively little difference ($p=0.39$ i.e. insignificant) with the engine recognizing 23.9 changes per minute for group 1 and 26.3 for group 2 on average.

The only variables with significant predictive value in the model were the pre-test result ($p<0.0001$), the duration of practice ($p=0.0015$) and whether the student had previously practiced independently (one of the form questions, $p=0.020$).

However, it is worth noting that in the average of 10.3 minutes of practicing (SD=4.9) that fit between the two tests, the chord changing speed improved from average 7.3s (SD=4.4) on pre-test to 4.2s (SD=2.1) on post-test, which results in a median improvement of 40.4%. Although this is still far longer than is required for even simple songs, the rate of improvement is still remarkable.

Discussion

We found that the more interactive condition did not result in decline in the effectiveness of the training as we did not detect any differences between the two learning conditions. The fact that the number of chords played by both groups on average did not differ significantly from each other means that both groups practiced evenly. Children did their best under both conditions by playing as fast as they could. So one explanation why the more interactive group did not get different results time might be similar to the one proposed by Liu et al. (2012) when they could not confirm one of the CTML effects: the positive effect of practicing was big enough to marginalize any possible negative effects coming from the learning design.

Secondly, it is possible the treatment time was just too short for any meaningful difference to become apparent, as the two tests took considerable time and the average practice time under different conditions was just around 10 minutes. However, with the current experiment design, getting longer practice times is very hard due to the limits set by the 45 min class and the pupils' sore fingers. Different types of experiment designs therefore have to be explored in order to study the problem further.

Conclusion

In this paper we introduced a technical solution that can help schoolchildren practice their speed of changing the basic guitar chord shapes. We built two sound recognition based applications that differ in the level of interaction to test the hypothesis that more interaction may hinder the learning. However, the hypothesis found no support as we found no significant difference in the gain of pupils' chord changing speed, nor did the more interactive condition make children practice more intensely.

The literature on music games in education has always underlined their potential to engage students and make them practice more than they otherwise would do. Our experience with more than one hundred pupils supports that opinion. Besides being highly engaged, the children also increased their playing skills considerably during the experiment. At the rate observed, it would take 2 to 4 lessons to achieve chord changing speeds that could be applied in real playing situations.

The reported experiences are limited to a very specific part of guitar education - that of practicing left hand chord shapes. However, every guitar student has to complete this stage in order to move on to more musical activities. Although the current paper reports the use of the two gamified applications in classroom setting, they are designed to work as individual practicing tools as well and can be made available online via the web.

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