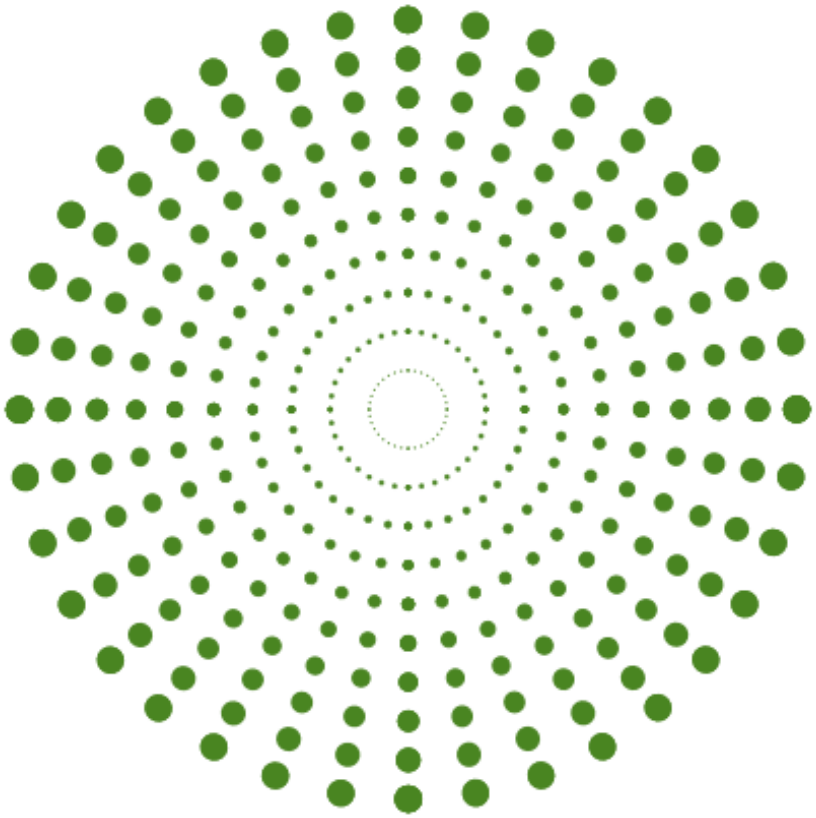


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Musical Android Game Design for Hearing Impaired Children

(Mahbuba Akhtar, İnci Zaim Gökbay)

Musical Android Game Design for Hearing Impaired Children

Mahbuba Akhtar[1], İnci Zaim Gökbay[2]
[1] *Graduate student, Istanbul University faculty of science, dept of Informatics,*
E-mail: hellomahbuba@gmail.com
[2] *Asst. Professor, Istanbul University faculty of Science, dept of Informatics,*
E-mail: inci.gokbay@istanbul.edu.tr

Summary: *Hearing loss (HL) refers to mild (26-40 decibel) to profound (equal or more than 90 decibel) loss of hearing in the better ear of an individual. Hearing impairment (HI) is a generic term popularly used to cover the entire range of HL. Globally, HI is the 4th leading cause of disability. In 2018, the estimated number of people living with disabling HL was over 466 million worldwide, which is about 6.1% of the world population. Among these people about 34 million are children. South Asia, Asia Pacific and Sub-Saharan Africa are regions with the highest prevalence of HI. Children coming from countries with lower literacy and per capita income are more likely to suffer from HI. Unless necessary actions are taken, the number of people living with profound HI is estimated to be 630 million by 2030 and subsequently 900 million by 2050. There have been some applications and games created in the past, to help individuals with HI in different areas of their lives. Some such games designed to facilitate HI children's speech and hearing therapies are: TheToy, DiDuDa, Into The Forest, Talking to Teo etc. This study discusses the design of a therapeutic musical video game created for HI children. The main aim of this study is to design an affordable musical video game application for HI children and their mentors and upon completion, collect user feedback. The games previously designed for HI children's therapy are more direct in their approaches, meaning, they generally target one area e.g. pronunciation, auditory attention or vocabulary and design the game to improve that specific area by training the users. Whereas in this game, our approach is founded on constructivism and indirect learning, where exercising some areas of music has the potential of improving some areas of language in HI children.*

Keywords: *hearing impairment, hearing impaired children, android game for HI, musical game, game language development.*

Introduction

Hearing loss (HL) refers to mild (26-40 dB) to profound (equal to or greater than 90 dB) loss of hearing in the better hearing ear of an individual [1]. Hearing impairment (HI) is a generic term popularly used to cover the entire range of hearing loss [2]. Hearing loss affects millions of people around the world and is estimated to be the fourth leading cause of disability around the world [3]. The most recent estimation presented in the year 2018, by WHO claims the number of people with disabling hearing loss to be over 466 million worldwide, which is close to 6.1% of the world's population. 93% among these people are adults and 7% (34 million) are children [4]. As seen in (figure 1. And 2.), Children from countries with low per capita income and literacy rate suffer more from disabling hearing loss compared to children from high-income regions of the world.

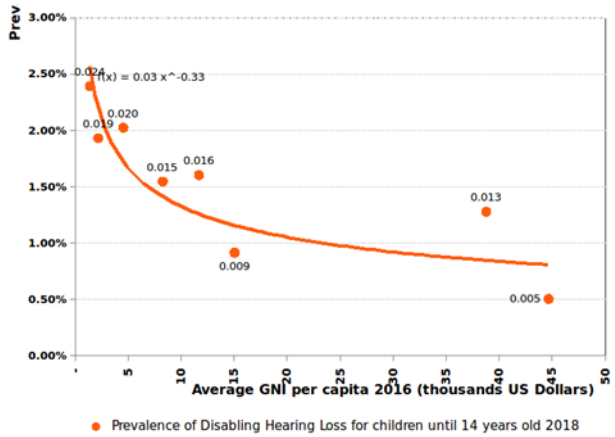


Figure 2. Correlation of per capita income and prevalence of DHL among children (1 to 14-year-old) in the year 2018 [3].

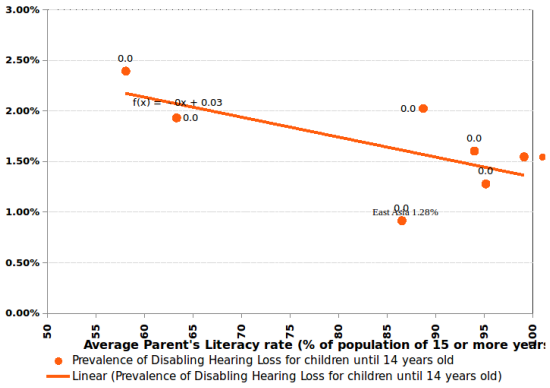


Figure 3. Relation between average parent's literacy rate (in percentage) and prevalence of DHL among children [4].

Also, statistically, South Asia, Asia Pacific and Sub-Saharan African regions, have a high prevalence of disabling hearing loss, almost four times higher than the high-income regions and also has the steepest growth curves till 2050 (figure 3.) [3].

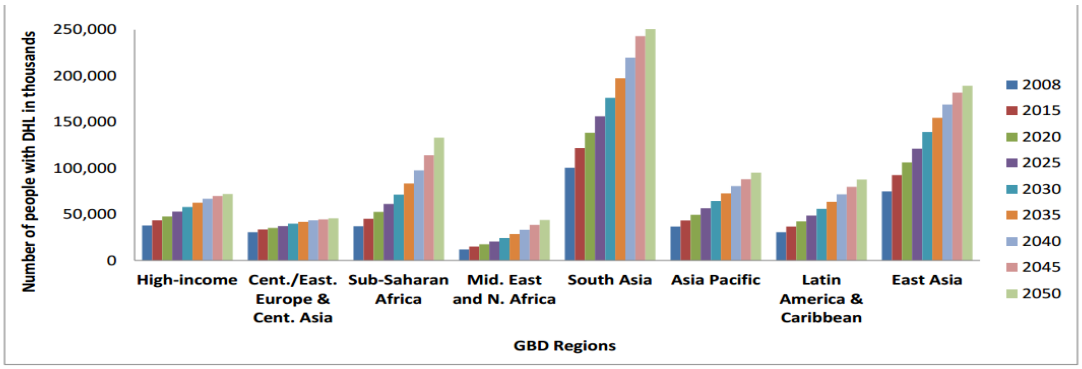


Figure 4. Global regional trend of the number of people with DHL from 2008 to 2050 [3].

On top of that, unless necessary actions are taken, there will be 630 million people living with Disabling Hearing Loss (DHL) by the year 2030; that number is expected to grow over 900 million by the year 2050 [3]. According to WHO, the estimated annual cost of unaddressed hearing loss exceeds 750 billion dollars globally [3].

Children with hearing impairment (HI) face many challenges in their academic and social lives. Most of the times hearing impairment in children are not diagnosed in the neonatal phase. This is why, it is very common that children grow a few years until their parents start noticing their hearing problem. Since a child's language development starts very early, the window of opportunity is often missed in late diagnosis and treatment. Hence despite getting aid or cochlear implants later on, HI children often suffer academically and are often outperformed by their hearing peers. The area in which HI children suffer the most is language development are: slower vocabulary development [5], lower working memory [6], difficulty in pronunciation of words, keeping up with fast speech, difficulty to concentrate, memorizing words and retrieving it quickly, Spelling [7], Lower pragmatic (verbal) skills [8] etc. As a result, in general, children, youth and older adults with HL show lower quality of life in different areas [9][10][11].

To mitigate the educational, especially lingual gap of HI children, several initiatives have been taken. One such initiative is to make the language learning process fun and easier using serious video games. There have been quite a few video games that were made for children with speech and hearing disabilities, such as TheToy, DiDuDa, Into the Forest [7], Talking to Teo [12] etc. These games take different design approaches while trying to create a support tool for HI children. In this study, we design a musical game with the same goal in mind.

Studies show that musical training improves various aspects of lingual abilities of HI children [13]. For speech and hearing therapy, music training is a particularly appealing candidate, since it promotes highly relevant cognitive skills, namely temporal prediction, hierarchical processing and auditory-motor interactions. This is why music training is continually becoming more common in the rehabilitation of HI individuals, especially for children. According to Patel, the reason for this is seemingly, shared sensory/cognitive processing mechanisms, as well as the fact that, compared to speech, music requires higher performance from these cognitive mechanisms. This is particularly true in cases of pitch and temporal processing as well as auditory scene analysis. Since making music requires a highly precise level of temporal synchronization, the ability to segregate the sounds of similar instruments etc., from a musician, it might be a good way to train those faculties of a HI individual as well [14].

The purpose of this study is to describe the development method of an Android musical game for HI children which will contribute in their lingual development. Upon developing the game, it has been given to a few HI children and their parents for testing. Their feedback about the game has been collected and analyzed.

Development

The learning approach used in the proposed game is based on "constructivism" instead of "instructivism" to promote learning of HI children. Constructivism theory talks about autonomous cognitive growth and learning as opposed to instructivism, where students learn via the instruction of their teacher. Recently constructivism theory has gained popularity. A foundational premise of this theory is that children actively construct their own knowledge

rather than simply absorbing ideas imparted to them by teachers. Constructive education can help improve child literacy in multiple ways, one of which is by using educational video games. Moreover, many studies have examined the use of mobile technology for formal and informal literacy, language learning, numeracy and math skill development. For schools that have limited educational resources and where traditional learning does not work, as well as for under-performing students; mobile learning devices can be quite effective [15]. To this end, instead of targeting a specific area e.g. spelling or pronunciation, in this game, some musical exercises have been designed that have been shown to improve specific areas of language in HI children.

Available literature show improvement in language skills of HI children after 6 to 18 months of musical training [13]. Musical training have shown to improve certain areas in HI individuals, such as perception of pitch, prosody, duration, timbre, temporal prediction, speech in noise and working memory [14]. While designing the game another fact has been kept in mind that, HI children show difficulty processing multiple choice questions compared to normal hearing children [16]. General guidelines for serious game design [17] and success factors [18] have been kept in mind while planning the game. Thus, based on the studies on musical training and hearing impairment, some music lessons have been designed specifically for HI children. The general entity-relationship and data flow diagram (figure 4.) and entity-relationship diagram (figure 5.) are given below.

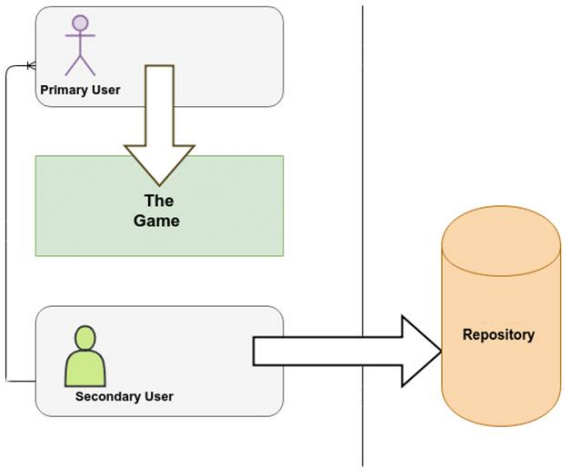


Figure 5. General entity-relationship and data flow diagram

As seen in (figure 4.) there are 2 types of users:

1. Primary user (HI children) and
2. Secondary user (the parent/therapist/teacher/mentor of primary user)

The child is the primary user, who plays the game. The secondary user does not play the game but uses the game to give feedback on the progress of the child, which is then saved in the memory of the Android device. Primary user can be one or a small group. The recommended group size for one device is less than 4 [19].

A more detailed entity-relationship diagram is given in (figure 5.) which shows the levels of the game. The game has 4 steps: Speech in Noise Exercise, Singing, Musical Memory Training, Learning Chords. Each step has levels with increasing difficulties. There is a scoring system as

well. Parental Panel is a questionnaire designed for secondary users, so that they can give feedback about the progress of the children. Parental Panel is independent entity from the rest of the game.

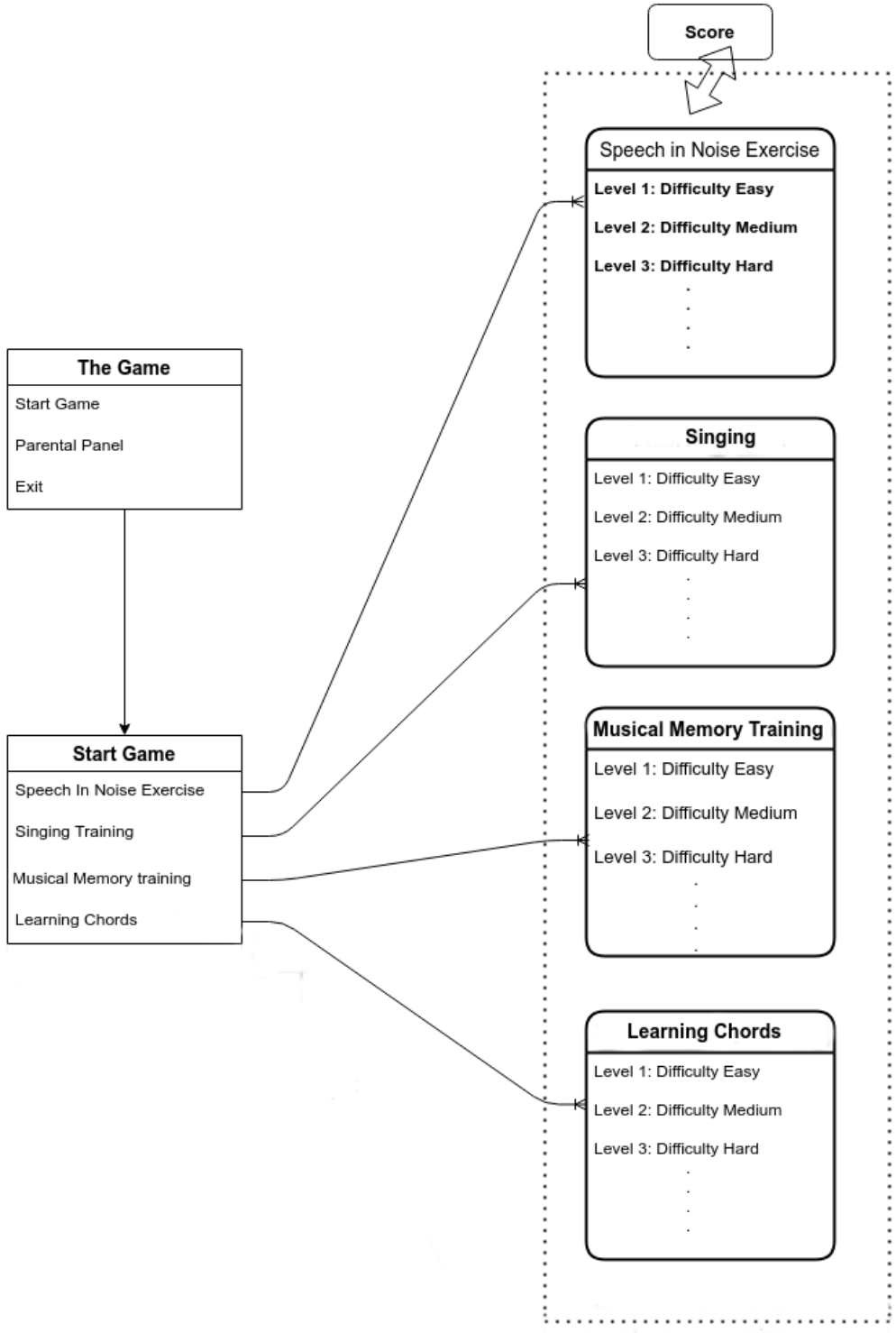


Figure 6. Entity-relationship diagram of the steps, levels, scoring system. Parental Panel is independent of any steps of the game.

For this game, we used a framework called Ionic. Ionic is a cross platform app development framework, which can be used to make Android and iOS application at the same time. For this project, AngularJS has also been used. While making an app on AngularJS the understanding of the following are important:

- HTML,
- CSS,
- JavaScript.

In the development process, Ionic has been installed on a Windows 10 operation system. The latest version of JDK (Java Development Kit) and Android Studio IDE (Integrated Development Environment) has also been installed prior to installing Ionic, which is the 14th version of JDK and 4.0 of Android Studio.

In summary the technical details for this development process are as follows:

- Windows 10 OS
- Angular JS
- Ionic framework
- JDK 14th version and
- Android Studio (release 4.0)

The game has been named Musicalfly. The game's user interface is shown in (figure 6.).

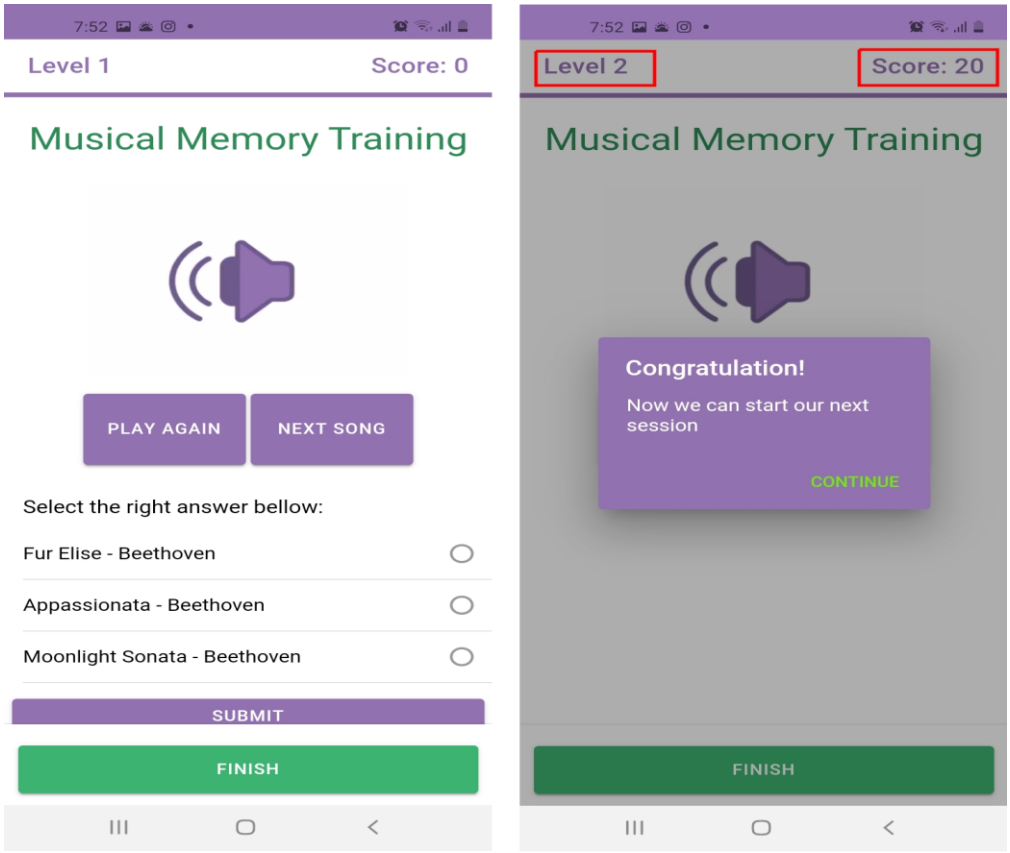


Figure 7. User interface of Musicalfly

Feedbacks have been collected from both primary and secondary users of Musicalfly. Two separate questionnaires were used to gather users' opinions and ratings. Below are two tables (table 1. And table 2.) containing the answers given by primary and secondary users of the game. Primary users are 12 children (6 boys and 6 girls) of ages 5- 12, out of whom 8 use cochlear implants and 4 use hearing aids. The secondary users are parents of these children (7 fathers, 5 mothers).

Table 1. Primary user feedback

Questions	Responses (N)						Total (N)
	Very Bad *(1)*	Bad *(2)*	Average *(3)*	Good *(4)*	Very Good *(5)*	Mean rating (x)	
On a scale of 1 to 5, how would you rate the "Sound in Noise Exercise" step of the game?	0	0	6	3	3	3.75	12
On a scale of 1 to 5, how would you rate the "Singing Training" step of the game?	0	0	1	6	5	4.33	12
On a scale of 1 to 5, how would you rate the "Musical Memory Training" step of the game?	0	0	3	5	4	4.08	12
On a scale of 1 to 5, how would you rate the "Learning Chords" step of the game?	0	0	0	7	5	4.42	12
What is your overall rating of the game?	0	0	0	9	3	4.25	12
Have you played the game?	Yes			No			12
	12			0			
Would you be interested in this type of game in the future?	Yes			No			12
	12			0			

As we can see in (table 1.),

100% of children have played the game.

The "Learning Chords" step of the game has received the highest mean rating from the children 88.4%

while the "Sound in Noise Exercise" has the lowest mean rating: 75%.

The average mean ratings of the remaining two steps are:

For "Singing Training": 86.6%

and for "Musical Memory Training": 81.6 %.

The overall mean rating of the game is 85%, and 100% of the children have shown interest to play the game in the future.

In the additional comment section, out of 12 participants, 2 complained of some of the music (specifically from Sound in Noise Exercise) to be too loud; 2 expressed liking the game and the rest offered some suggestions. Some suggested adding funny or famous music and rhymes, some asked for songs in different languages. Other suggestions were to improve "Musical Memory Training" and making "Learning Chords" more fun.

Table 2. Secondary user feedback

Questions	Responses (N)						Total (N)
	Very Bad *(1)*	Bad *(2)*	Average *(3)*	Good *(4)*	Very Good *(5)*	Mean rating (x)	
On a scale of 1 to 5, how would you rate the Parental Panel?	0	0	3	5	4	4.1	12
Did you check out the game (except the Parental Panel)?	Yes			No			12
	12			0			
Do you think this game has the potential to be useful to your child?	Yes			No			12
	12			0			

As we can see in (table 2.) the (arithmetic) mean rating for the parental panel in percentage is: 82%

100% of the participants have tried the Parental Panel and

100% thinks the game has potential to be useful to their children.

In response to "what do you think of the 'Parental Panel'?" overwhelmingly the parents' responses were positive. Out of 12 parents, 10 praised the inclusion of the panel, and 2 offered constructive criticism ("… more information can be added" and "… Parental Panel can be more descriptive").

In the additional commentary section (question 5) of the survey, 1 parent praised the game, 3 offered no comments, the rest of the suggestions included - advices to add variation in the

music, color and background; make the UI more user friendly, improve the sound quality, adding more features and making the music of the game subtler.

Discussion

Music recently is being used for therapy in many areas. Extensive control-group experiment done on this topic is still quite lacking. However, currently it is being considered as one of the promising ways to improve the cognitive functions of HI individuals. With that aim in mind, Musicalfly has been created. For hearing impaired individuals' musical therapy can not only be beneficial, but can also bring joy and social engagement. In view of the feedbacks received from the parents and children we can safely assume that the user response for this game is significantly positive.

Due to time and resource constraints the game could not be tested over a minimum period of 6 months, which is a future scope of this study.

Conclusion

Therapies can be very expensive. Many families could benefit from some therapy tools at their hand. Not to mention speech therapists can take advantage of this tool to help their patients. With the increasing affordability of mobile technology, people from many different walks of life now have access to some or other type of mobile devices. Keeping that in mind, in this paper we explained the process of creating an Android video game application as an affordable supporting therapeutic tool for HI children. A strong motivation of this study was to make therapy a little less expensive and readily accessible to HI children.

Moreover, since the spread of COVID-19, many rehabilitation facilities has been shut down, including many for hearing disability. Available apps or games for therapy is surely not a replacement of regular therapy, but can be a good way to continue improving, rather than waiting for rehabilitation facilities to open.

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