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Augmented reality games for children with cerebral palsy

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Abstract. This paper describes and discusses the development of mobile exergames for children with cerebral palsy. The design process was built on co-design, and resulted in three activity games, two augmented reality (AR) games and one GPS based game. The resulting activity games were evaluated by 8 persons with cerebral palsy (CP). To complement this evaluation, the games have been evaluated against existing guidelines for accessible games. The developed games provide a proof of concept of how mobile games can be designed to encourage physical activity for children with mobility impairments.

Keywords: Physical activity, Cerebral Palsy, Exergame.

1 Introduction

1.1 Background

Children and adults with cerebral palsy (CP) often participate less in physical activities, and have reduced health related fitness (muscle strength and cardiorespiratory endurance) [1], having a higher risk for negative health outcomes; eg cardiovascular disease. CP is also often associated with pain, making physical activity less attractive. At the same time, exercise can both improve fitness/function and reduce pain [2]. It is thus important to find ways to make physical activity motivating, in order to encourage children, as well as adults, with these kinds of problems to become more physically active. Video exergames have been successfully developed for children with CP [3], however video games require special equipment which is both costly and which is also tied to a specific location.

With the success of Pokémon Go, it has become clear that mobile games can promote physical activity, and that they may reach populations who are otherwise typically difficult to reach (those with established sedentary behaviors) [4]. Unfortunately, many mainstream games may be difficult to interact with for a person disabilities [5], and there is a need for more games developed for this user group.

1.2 Project GameA

The aim of the project GameA was to develop activity games specially designed for children with mobility impairments such as Cerebral Palsy (CP) or Spina bifida (MMC). The goal of these activity games should be to encourage movement and

counteract a sedentary lifestyle. They should also be adapted to the abilities of our user group, while being inclusive. Within the framework of this project different technologies and designs were investigated. The project was based on co-design, and started with workshops together with users, to gather ideas and evaluate different types of technology. Covid-19 then prevented physical meetings, which meant that we had to collect opinions digitally, as well as through informal contacts with children with and without mobility impairments. The design process resulted in three activity games, two AR games and one GPS based game. We also have an overall game app "PlantAliens" incorporating the two AR games, where you develop characters by collecting points in the activity games. The app is available for iPhone[1] and Android[2]. The activity games in PlantAliens were evaluated by 8 persons with CP who rated the AR games as easy to understand and play, and on average judged the speed/difficulty as "appropriate". To complement this evaluation, the games have been evaluated against existing guidelines for accessible games.

The project team consisted of researchers from the Department of Design Sciences, Lund University, Do-Fi - a game company, RBU Skåne and Funkibator – end user organizations, Musik i Syd – an organization working with music for children, who had an existing app for children called MusikA, and a physiotherapist and health science researcher from Lund University, Annika Lundkvist Josenby, specialized in pediatrics/neurological disorders and with clinical experience of working the target user group. The project had ethical approval (2019-04069).

2 Design process

After the initial brainstorms in the project team, it was decided together with our clinical expert not to focus on specific movements where the challenge is to perform the movement correctly, but rather to focus on encouraging movements involving the whole body such as standing or walking. In order to get initial input from our user group, we organized a technology exploration workshop. For this workshop we collected a set of existing games and demos, which all relied on physical movement for the interaction, didn't require strength/endurance and worked in a smaller area/indoors. We had a NFC-tag treasure hunt, an audio game where the phone would produce different sounds depending on how it was moved, an augmented reality (AR) game where you killed bugs and a step counting game where you could collect keys and chests (the keys would unlock the chests). Two young persons with CP attended this workshop and explored and discussed the different games. This workshop was followed by a study visit/workshop at the end user organization Funkibator, which (among other things) organizes game sessions for persons with disabilities, where we tested VR games, dance mats and also discussed the mobile games from our earlier workshop with end users. Based on the results from these two activities, we decided to focus the development primarily around AR games. The bug-shooter AR game was very clearly the most popular game at the user workshop, but AR games also have several

[1] https://apps.apple.com/se/app/plantaliens/id1547433659

[2] https://play.google.com/store/apps/details?id=com.DoFi.PlantAliens

advantages from a more technical perspective; given that AR uses the video stream from the camera, they are less heavy from a development point of view (no need to create virtual environments, it is enough to create virtual characters), AR works anywhere and doesn't necessarily require strength or endurance. In a parallel design process within a master thesis project, an additional GPS based game was developed.

At this stage in the project, the Covid pandemic hit, and all project activities had to be move on-line. While the development could continue fairly unhindered, user activities became more problematic. We were able to get some users to test game prototypes informally, but user workshops were harder. Normally, we in the research team would install and do all setup for the users (while finished apps should be easy to install and set up, prototypes are less finished and often require more tech support), but when testing is done remotely, the user or someone close to the user has to take care of the setup procedure. This turned out to be a significant hurdle, and we had to rely mainly on informal testing by persons that participants in the project were able to meet during the development process. Since the project involved both end user organizations as well as a clinician this still provided useful input, but it was a restriction. Once we had more finished prototypes, we were able to distribute our games for testing digitally, and our final game designs were tested by 8 persons with cerebral palsy (one teenager, 5 young adults, and two adults). In this final evaluation, the AR games were rated as easy to understand and play and the speed/difficulty was on average judged as "appropriate". The GPS game was built on MapBox, and unfortunately suffered from technical problems (not loading, freezing) which impacted on the user experience (about half of the testers found it easy while the rest rated the difficulty as neutral or hard). Given these technical problems, the GPS based app was not included in the released version of PlantAliens.

To complement the user evaluation, we also did a heuristic evaluation based on the Game Accessibility Guidelines [3]. In general the games follow these guidelines well, the user can select distances/difficulty, interactive elements are not too many, and are fairly big/easy to see, the game do not require great fine motor precision (eg the gun for shooting bugs fires automatically), sounds complement the visual feedback, and the games work both in landscape and portrait orientation. Still, we can also see room for improvement; more settings might make the games even more adaptable, more instructions could potentially be included in the games and of course, the games could involve even more levels/more development over time.

3 Game design

Two AR games were designed. In one, the user can catch objects (clouds) by moving the whole phone close to the object, in the other the user can point towards a target (bugs) to shoot it. The shooting triggers automatically once the phone is pointing towards a potential target. You have to keep pointing in the same direction in order to hit the target with a couple of shots before it explodes.

[3] http://gameaccessibilityguidelines.com

The two games are set within an overall framework where you collect some kind of alien plants (“PlantAliens”), in the AR games you collect resources in order to nurture your plants and unlock new ones. The AR games increase in difficulty – initially targets keep still, but as you progress in the game they fade away faster (clouds) or start moving (bugs). The game area is selected every time you start the game, for the clouds you have four choices (close in front, middle in front, middle all around and far all around), while for the bugs there are two choices, in front or all around. Graphical elements that reflect different abilities, eg figures with wheels/wheelchair are included.

Fig. 1. Screen shots from the cloud game (left) and bug game (right).

In the GPS game, the goal was to collect stars, and it allowed the user to select short, medium or long distances. The game was initially intended to be used together with the AR games to unlock game features, but due to the technical problems experienced, the GPS game was not included in the final PlantAliens app. If included, the game would have allowed users to choose freely which game to play, in order to cater to differences in abilities and preferences.

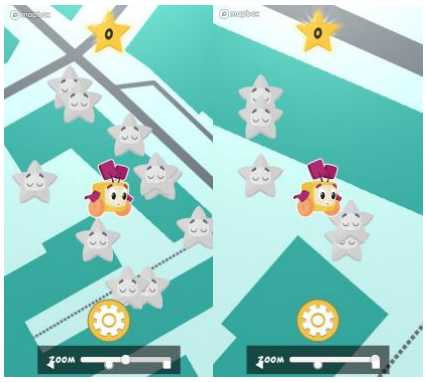

Fig. 2. Screen shots from the GPS game at two different map zoom levels. The user avatar is the yellow/red figure in the middle. When you get close to a star it wakes up, and you can catch it.

3.1 Game area

A general challenge in the game development has been how to adapt it to different abilities. It should be possible to play the game from sitting, as well as from standing (with different abilities to move around). Our initial design was based on an enclosed area where one could move the corners of the area in order to get the correct shape (fig 3). In order to change the shape, the user could point the cross hair to a corner-ball, put a finger anywhere on the screen, and then move the ball/corner by moving the whole phone in space until it was in the right place.

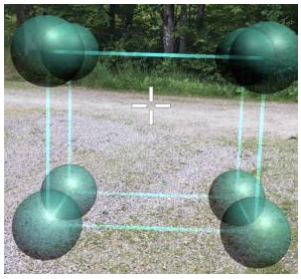

Fig. 3. Enclosed game area. The corners could be moved into any position separately, and it was also possible to move the whole shape to a new position.

Putting the finger on the screen with the cursor not on a ball, would select all the balls, and you could then move the whole shape by moving the phone. In the final version of the games, this was changed to pre-determined game areas (fig 4).

Fig. 4. Pre-determined game areas. In front of you or around you (bugs) or in front close, in front medium, all around medium and all around far (clouds).

4 Discussion and conclusion

The developed games provide a proof of concept of how mobile AR games can be designed to encourage physical activity for children with mobility impairments (CP). In earlier projects eg [6], we had done both graphic and sound design ourselves (relying on bought material from shutterstock.com and freesound.org), while in this project we had the privilege to work with both graphic game designers and a musician, something which, as expected, made a huge difference.

By relying on AR, it is possible to design games which require quite limited movements, which are fun/engaging and which can be played anywhere there is a suitable environment.

A difficulty we struggled with during the development was the adaptation of the game area. For a person with limited mobility, it is crucial that the game can be restricted to a suitable space – it is no fun if you get stuck in a game simply because you cannot reach/hit a target. Our initial version of the games included a game area setting, where you could drag the corners of the game area into any configuration you wanted. Once you had the desired configuration it was saved and could be re-used. However, the exact location of the center of the game area would usually need to be adjusted every time, since the origin location in the AR coordinate system was where the game was started. While tests showed the initial design was in principle a working solution (the persons who tested it were able to use it), it turned out to be cumbersome. Thus, we decided to scrap this very flexible design for one with pre-set game areas. More research on how to make this type of games more flexible and adaptable, while keeping them simple and usable is needed. Still, the interaction by physically dragging virtual object, moving them by moving the whole phone worked well in itself, and could potentially be used in other contexts, eg. in puzzle games where you should move objects into the correct position.

In this kind of development, one typically relies on existing packages/environments. In the project we used Unity and existing AR packages, which generally worked well, and which allowed us to create apps both for iOS and Android. Games like these also need to work when connectivity is poor or non-existing. The GPS game relied on MapBox, and it turned out the prototype required both a working network connection as well as GPS. Unfortunately, we were unable to make it independent of connection quality within the limited time frame available. It is always a trade off between building from scratch (providing full control), and relying on code written by others (you get a lot for free, but can run into difficulties when problems occur).

Long term use remains a challenge. It is well known that players tend to lose interest in games after some time [7]. Design features recommended for engagement in AR games in general, such as outdoor and physical activities, teaming up, exploring formerly unknown environments, collection of in-game items, such as capturing Pokémon and competition and fights [8], may still be useful but need special consideration. In the presented games we relied mostly on the collection of in-game items, in combination with physical and potentially outdoor activities. Given the scarcity of exergames for our user group, further research and development on this point is important.

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