Fontan Quest: A gamified mobile application for parents and children that underwent Fontan surgery to engage in physical activity

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Abstract

Exercise training is advised for children who have undergone a Fontan procedure due to its potential benefits such as improvement in cardiopulmonary capacity. However, parents are frequently a stopper to this goal. This paper proposes a gamified app, named Fontan Quest, which will focus on engaging Fontan patients with physical activity whilst collecting data such as weekly exercise time. This data will then be shared with parents so that they are involved and aware of the benefits exercise brings to their children. The app's acceptance by parents and children was evaluated using User Experience Questionnaires. This study indicated an area of improvement related to gaming design to increase participation of parents and children of a younger age. Fontan children and their parents accepted this innovative approach.

Keywords: Fontan operation, exercise capacity, childhood, gamified app

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1 Introduction

Patients after Fontan repair, performed to treat several complex congenital heart abnormalities, are more sedentary than their healthy peers and do not achieve daily levels of moderate to vigorous exercise as recommended. This is often a consequence of parents who are uncertain about the recommended physical activity for their children [4].

Several studies emphasize the positive impact of physical exercise in Fontan patients [6][7][3]. Nevertheless, the exercise programs used to assess the improvement of patient's exercise time were training programs not aimed to kids.

The use of gamified apps with a serious purpose, has been increasingly popular to involve children in programs to improve their health. [1] However, no studies have specifically focused on the testing of a mobile application (app) to encourage physical activity in Fontan patients.

Therefore, a gamified mobile application was developed directed at children ages 6-12 who unterwent Fontan surgery, and their parents. The main aim of the app is to increase physical exercise time each week for Fontan kids with a gamified approach and to influence their parents' perceptions about exercise by including a parents' section within the app.

2 Fontan Quest App

The supporting platform, entitled Fontan Quest, consists of two parts: The "Parents' Section" and the main game. The decision to integrate both sections within the same app was due to the frequent use of parents' smartphones for gaming purposes by children.

The previous sections were created using Unity and will be integrated with the Flutter framework for application building. This integration will allow for the collection of activity data from the child's smartwatch, which will then be displayed in the "Parents' Section". [1] The activity data will also be connected to the main game so that the children

[1]Page written by Laura Rabadan

receive resources when performing exercise outside of the game.

Fontan Quest is divided into three parts embedded on the phone in Flutter. The following section explains the parent's section in detail, listing its content and its requirements. Part 4 explains the implemented mini-games, both indoor and outdoor, stating their respective gamification ideas. Part 5 shows the implementation of an Real-time strategy (RTS) game in a village-like setting for long-term motivation. The following part deals with the embedding of the previous parts programmed in Unity into Flutter in order to connect it with a Google Health API.

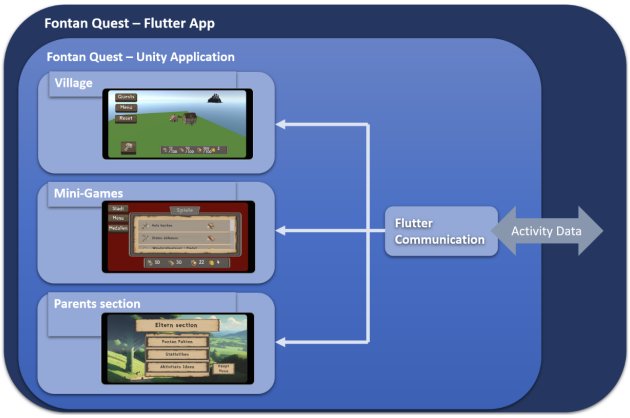

Figure 1. Software Architecture of Fontan Quest

[2]

3 Parents' Section

The parents' section concentrates on providing Fontan children's parents with (1) statistics regarding their children's physical activity and gameplay, (2) activity suggestions to do with their children, and (3) facts from previous studies proving that physical activity in Fontan patients is not only beneficial, but necessary.

The data presented in the "Statistics" section within the "Parents' Section" is: weekly exercise time, daily steps and overall playing time. By providing parents with this information, the parents' section motivates them to take an active role in their children's physical activity and encourages a healthy and active lifestyle for the entire family.

3.1 Requirements for the Parents' section

The primary focus of the parents' section is to collect data from the main app to present to the parents. Therefore, the target audience of this section is parents between the ages of 25-55 so the user interface (UI) must be simple and intuitive enough for parents of all ages, even if they are not familiar with technology. In addition, the information included should keep the parents engaged in learning more about their children's physical activity performance, both inside and outside the app. [3]

4 Minigames

4.1 Requirements for the minigames

While the goal of the village game is to motivate children to play the game regularly and gain new resources to build the village, the mini games should motivate children to be more physically active. Since the app is targeting Fontan children aged nine to twelve, the mini-games should cover a wide range of topics and interests of children of this age. The games also need to cover different levels of difficulty and a wide range of fitness levels of the players. That is why the games in Fontan Quest vary in length, intensity, and theme, so that everyone can find games which suit their level and interests.

The goal of Fontan Quest is to make children more active in general, which means that they should exercise not only outside on sunny days, but also inside on rainy days. To achieve this, outdoor and indoor games have been implemented. Whereas indoor games need to be playable in small spaces, outdoor games can include walks with longer distances.

4.2 Indoor games

Two mini games have been developed for indoor games. The stone mining game and the wood chopping game. Both are based on the same mechanics and require the children to have access to the smartphone. They must make quick chopping and mining movements with the smartphone to collect more wood and stones for their village. To detect the movement, the phone's accelerometer is used. The player is rewarded directly after he completed the game. If more wood was chopped, the player will also get more wood. The game has a length of 20 seconds, and the intensity depends on the player's motivation to chop as much wood or mine as many stones as he can and his fitness level.

4.3 Outdoor games

"Finde das Heilmittel" is an outdoor hiking game where the player can choose between different difficulty levels that determine the length of the hike. The player can choose between 2000, 4000 and 8000 steps.

In the game, the player is taken through a story in which the evil wizard has cursed the village and the player must find all the ingredients to make a cure for the villagers. To find the ingredients, the player must walk a certain number of steps, solve puzzles, find objects in 3D scenes, and run away from an angry bear. The game is suitable for children and their parents to play the game together, spend time

[2]Section written by Md Iftekharul Alam

[3]Section written by Laura Rabadan

outdoors and become more active by taking short or even longer walks.

4.4 References to YouTube content

Fontan Quest takes advantage of the variety of children's content on YouTube. Many people have created content for children, such as workouts with different stories and animations or tutorials for soccer tricks, etc.. In the mini-game section, kids have a selection of YouTube links to reviewed content. Which covers different fitness levels and a variety of topics. In the future, the fitness tracker could measure daily activity and completing a YouTube workout could be indirectly rewarded by daily activity. [4]

5 Real-time strategy (RTS) village game

5.1 The need of long-term motivation

Given the many distractions in our fast-paced world, the nature of Fontan Quest requiring physical activity for people potentially unused to it, a long term motivation is needed that also connects the seperate minigames into a coherent story. The combination of story and strategy is also important because of the diverse target age group, assuming that younger children might enjoy less long-term, resourceful planning but an intriguing story. Older children, on the other hand, might enjoy both gameplays but could also seek more autonomy and self-efficacy.

5.2 Core mechanics

The core ideas behind the RTS game are city planning, resource management, and interaction with fictional characters. This reflects autonomy, self-efficacy and storytelling.

5.2.1 City Planning. Players can build seven types of buildings (wood cutter, stone mine, farm, castle, tavern, house, stables), each enabling the workers to fulfill distinctive tasks. The first three building types allow resource generation whereas the castle increases the maximum storage capacity. The tavern makes workers finish their tasks faster but requires food for it. The stable is a generic building to link the mini-games directly into the village environment in the future. The house allows more workers whereas the castle increases the overall storage. The player is given much autonomy in city planning. An empty island is provided allowing buildings everywhere on-top of it. The buildings are movable and rotatable by the player before building. Once built, each building has three levels which improve their benefits gradually.

5.2.2 Resource Management. Wood, stone an food can be gathered by the workers through the respective buildings. Using Unity's nav mesh agent script, they find the paths to their tasks dynamically. Resources are needed for any new building or to upgrade one. However, gold is also needed

Figure 2. Building the village with a free worker waiting for a task to be given by a building

which can only be gathered through sportive activities such as mini games. In addition, the overall steps made since the last start of the game amount to up to three gold. Three gold are also given when first starting the game.

5.2.3 On-boarding and the gaming experience. Once entering the game for the first time, the initial story begins, presented through a dynamic message system, separating longer texts automatically, displaying the talking person with animations and storing messages that are triggered at the same time. At first, the player's advisor is introduced explaining that king Peter-Emiliard has sent the player to build an outpost on the island shown right after. As soon as the player follows the advisor's advice to build something, the antagonistic wizard Radion complains about the player's presence. He appears again in the minigames and, therefore, links the RTS game with sportive activities. In the following gameplay, the advisor gives further hints about each building type, comments the player's sportive activities and suggests ideas for village adjustments. [5]

Figure 3. The first message by Radion about the player's presence

[4] Section written by Alisa Schulz

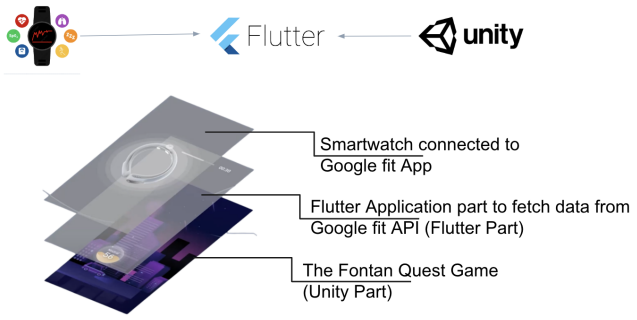

Figure 4. Proposed Approach [2]

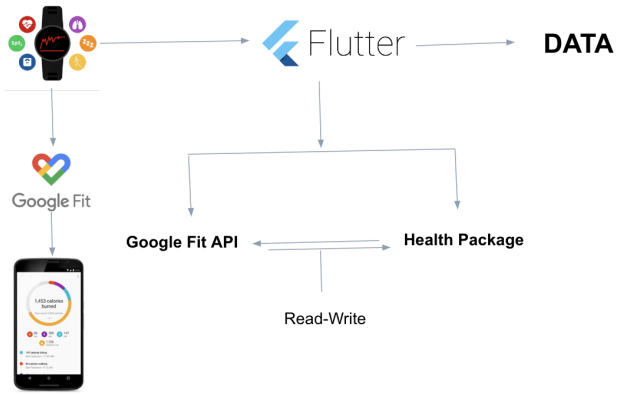

Figure 5. Smartwatch to flutter connection

6 Smartwatch Connection and Data

6.1 Fontan Quest and Flutter

Our game, Fontan Quest, is a unique combination of Unity and Flutter technology. To integrate our Unity game into a Flutter application, we utilized the 'flutter_unity_widget' [8] package. This package provides a platform-independent bridge between Unity and Flutter, allowing for seamless integration of the two technologies. Our main goal was to use data from a smartwatch in our mobile game made with Unity. Despite extensive investigation, we encountered a considerable challenge in finding an expedient solution to capture data from the smartwatch to Unity. Upon further exploration, we discovered that Flutter offers a rapid and convenient method to extract data from the smartwatch. Furthermore, as our game was intended for mobile devices, we were able to effortlessly integrate Flutter, a mobile application development platform. Additionally, we observed that Flutter is compatible with Unity, and Unity games can be incorporated into Flutter applications, allowing for seamless communication between the two platforms.

6.2 Smartwatch to Flutter

Our Flutter application employs the 'health package', which leverages the Google Fit API to extract data from the smartwatch. To utilize this package, it is necessary to first establish a connection between the smartwatch and the Google Fit application on the smartphone. Once this connection is established, the Flutter app can utilize the 'health package' [5] to connect with the Google Fit API and access health data, both for reading and writing. Subsequently, these data are fed into the Unity segment of the application.

6.3 Unity game integration into Flutter App

We have adopted the 'flutter_unity_widget' for integrating the Unity game into the Flutter application. This package is an asset for Unity, and importing the 'flutter_unity_widget' package into Unity enables a Flutter option within the Unity environment. As a result, the game can be exported as an Android JAR class later, and this can be displayed as a widget in the Flutter application user interface.

6.4 Flutter-Unity Communication

The 'flutter_unity_widget' package facilitates the invocation of a Dart code function from within a C# script in Unity. This is accomplished by specifying the game object and the specific function name. We are able to transmit various metrics such as steps and heart rate from the Flutter environment by utilizing the function as a string and receiving the data by calling the same function from the Unity platform. [6]

Figure 6. Flutter-Unity Communication

7 User study

7.1 Numerical results

In order to know which aspects of the game to develop further, change or dismiss, it is necessary to receive as much user feedback as possible. A survey with 30 participants (40 percent female) was conducted. The average age was 23,4 with 2 children and the participants were mostly students. Two additional children were asked about feedback but not as part of the survey. Although 43,3 percent said to never play video games, the average rating for "ease of use" on a scale of 1 to 5 with 1 as very difficult and 5 as very easy,

[5]Section written by Hannes Jacobi

[6]Section written by Md Iftekharul Alam

Table 1. Participants' acceptance assessment (N = 30)

How much do you agree with the following about Fontan Quest?	Agree (%)	Median (range)
"Was it fun to play?"	86	5
"Was it easy to use?"	86	4
"Do you think the prototype fulfills its purpose?"	83	5

Users who agree with the statement include two highest scores and positive answers depending on the question.

was 4,3. The overall grade on a scale of 1 to 5 with 1 as not good and 5 as very good was 4,41 on average. However, most important is the written feedback criticising the game or highlighting it's positive aspects.

7.2 Textual feedback

The main negative feedback targeted unfinished aspects of the game, such as bugs - mentioned directly or indirectly by seven participants. In addition, some mechanics were criticised such as the moving of the camera on the island or the lack of a rotation possibility for the camera. Zooming was expected as well and the building system should have been more intuitive, criticised one participant respectively.

The minigames were criticised for the necessity of "killing" the bear, for the "confusing" questions, the risk of throwing the phone when shaking it and for having to do much sport. Most people liked the interface and game graphics, although some disagreed, but there was overall positive feedback about the creativity put into the diverse motivational parts. Many said to have fun playing, and that it was easy to play and motivated them to do sports. Positive feedback was given to each mini game specifically and to the RTS game as well. Overall, the possibility to select out of so many games was liked.

Feedback from the Parents' section indicated a need to exclude some repetitive facts while adding more information about exercise routines recommended for children. It was also suggested to add more metrics about children's health in the statistics section.

Finally, people gave feedback on the question whether they think the game fulfills it's purpose in motivating Fontan kids to do sports and to take away the fear of parents in letting their kids embrace physical activities. 25 answered with yes, two with no and the rest with ambiguous answers. With the vast majority agreeing, criticism targeted the lack of social interaction with others, a possible to overwhelming entry to the game, and the need to much sportive activities. It was especially liked that the games were a safe environment to do physical exercise both indoors and outdoors and that the overall app was fun to play.

[7]

8 Conclusion

Based on the results of the conducted user study, it was observed that the developed application has the potential to increase exercise time in children who underwent Fontan surgery. Furthermore, the Fontan Quest app has the ability to positively influence parents' perception regarding their child's physical activity performance. Despite its favorable initial impact, the Fontan Quest app could be further improved by providing additional information in the "Parents' section" such as peak heart rate and peak oxygen volume in the "Statistics" section, as well as recommended exercise routines for kids. Additionally, simplifying the village section for a younger audience, and slightly modifying and adding more minigames may enhance its appeal and engagement. Finally, bugs and game mechanics should be fixed.

Overall, a gamified exercise training program may be one of the promising strategies in the management of physical activity in younger Fontan patients. [8]

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A Overview of work distribution

The implementation of the app was distributed in the following manner:

- Alisa: Minigames implementation.
- Hannes: RTS Village game implementation.

[7] Section written by Hannes Jacobi
[8] Section written by Laura Rabadan

- Md Iftekharul: Smartwatch connection and data collection.
- Laura: Parents' section.

B Declaration of Academic Integrity

Ich versichere, dass ich die Arbeit ohne fremde Hilfe und ohne Benutzung anderer als der angegebenen Quellen angefertigt habe und dass die Arbeit in gleicher oder ähnlicher Form noch keiner anderen Prüfungsbehörde vorgelegen hat und von dieser als Teil einer Prüfungsleistung angenommen wurde. Alle Ausführungen, die wörtlich oder sinngemäß übernommen wurden, sind als solche gekennzeichnet. Auf den Einsatz von Diensten zur Generierung von Texten mit der Hilfe künstlicher Intelligenz wurde verzichtet.

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