Sorterius - An Augmented Reality App for Encouraging Outdoor Physical Activity for People with Intellectual Disabilities

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Abstract
Many with intellectual disabilities (ID) have difficulties adhering to current physical activity guidelines. The goal of this study was to develop a mobile app for assisting people with ID to be more physically active. We implemented a solution that combines the digital and real world using augmented reality (AR). Eight people working with people with ID (special education teachers, social workers, psychologists, and researchers) tested the app and completed a usability test. Results indicate that a mobile app focusing on everyday life scenarios can have a potential value for the targeted user group, but AR solutions can be challenging.

Keywords
Motivation, mHealth, mobile health, exergames, steps, smartphone

1 INTRODUCTION

Physical activity (PA) provides significant health benefits [1], and the World Health Organization (WHO) recommends young adults to perform at least 150 minutes of moderate PA every week [2]. However, people with intellectual disabilities (ID) are known to have difficulties achieving these recommendations [3]. Compared to the general population, they have lower PA levels and worse health [4; 3]. One of the barriers for participation in PA for individuals with ID is lack of interest and low PA related self-efficacy [5]. However, motivation for PA could be triggered by fun, use of rewards, and technology [6].

The availability of mobile applications (apps) for improving and motivating PA has greatly improved the last decades [7]. However, apps tend to generally be too complex for people with ID. It follows that people with ID need tailored apps that can motivate them and increase their PA [8]. The goal of this study was to develop an app for assisting people with ID to be more physically active. The app is part of an ongoing intervention with people with ID and is currently being tested and evaluated [9; 10].

2 METHOD

We implemented Sorterius, a Pokémon Go-inspired cross-platform app using the Unity game engine (Unity Technologies, SF, US, v2019.4).

The game uses augmented reality (AR), where players observe the real world through the smart phone camera. Digital content, in the form of 3D garbage objects, appears on the screen as the player walks around. Sorterius is based on previous work by Haugland et al. [11; 12]. A thorough description of the design and implementation of Sorterius is described by Stellander [13].

The player's goal is to help the game mascot, *Sorterius*, to clean the world. This is achieved by picking up virtual garbage as it appears on the screen (by tapping them). Players must correctly choose between several containers to throw the garbage in, depending on difficult level. The player can choose between three difficulty levels: *easy* (one garbage container), *medium* (two containers), and *hard* (four containers). An internal step counter is used to determine how often new garbage objects should appear. Players are rewarded with daily virtual rewards, in the form of *stars* and positive feedback. A caretaker menu allows customization of level difficulty and to define the daily step goal and weekly star goal. Completing the daily step goal awards three stars. In addition, to further motivate usage, physical rewards can be defined (e.g., movie tickets), which will be awarded by the caretaker upon achieving the weekly star goal. Text-to-speech options can be enabled for players with limited reading skills.

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Due to restrictive infection control measures related to the Covid-19 pandemic, we were unable to test the app in the target group. However, eight people with relevant background, i.e., special education teachers, social workers, psychologists, and researchers working with people with ID, tested the app, completed a System Usability Scale (SUS) questionnaire, and gave general open-ended comments to the solution. A SUS is used for collecting feedback on subjective aspects of usability of a system [14]. The scale is a 10-question questionnaire, where answers are given on a 5-point liker scale, ranging from *strongly disagree* to *strongly agree*. We customized the SUS questionnaire to address the limitation of who completed the questionnaire. Table 1 gives a list of the 10 customized questions.

#	Question
Q1	I think the application would be regularly used by people with an intellectual disability
Q2	I think the application is too complicated for people with an intellectual disability
Q3	I think the application is easy to use for people with an intellectual disability
Q4	I think a person with an intellectual disability would need support to use the application
Q5	I think a person with an intellectual disability would think the different parts of the application are well connected
Q6	I think a person with an intellectual disability would think there are too many inconsistencies in the application
Q7	I think a person with an intellectual disability would be able to learn to how to use the application
Q8	I think the application is too difficult to use for a person with an intellectual disability
Q9	I think a person with an intellectual disability would be comfortable using the application alone
Q10	I think it will require extensive training before this application can be used

Table 1. Customized System Usability Scale (SUS) questions

Individual SUS scores for each question were calculated by subtracting one point (i.e., score-1) from all odd questions (positive polarity), whereas for even questions (negative polarity), participant responses were subtracted from five (i.e., 5-score) This gives 0-4 points for each question. Scores for all participants were added and multiplied by 2.5 to create a scale from 0-100 for each question. According to Sauro et al. [15], a score of 68 is an average score when analysed as a percentile rank and can be considered as a "Satisfactory" system. Alternatively, Bangor et al. [16] defined an acceptability scale, where a SUS score above 70 is considered "Acceptable".

3 RESULTS

Figure 1 shows two game play screenshots, showing the visualization of the garbage on screen using AR. The app achieved an overall SUS score of 61. This is somewhat lower than the average score mentioned above of 68 [15] and corresponds to a "marginally acceptable" [16] system. Participant's individual SUS scores ranged from 42.5 to 80.0, where half of participants gave a SUS score of 65 or higher. Individual raw (i.e., before inverting negatively framed questions and before multiplying with 2.5 to create 0-100 scale) SUS scores ranged from 2.1 to 3.9. An overview of SUS (range 1-5) mean and standard deviation for each question is given in Table 2. For questions Q1, Q3,

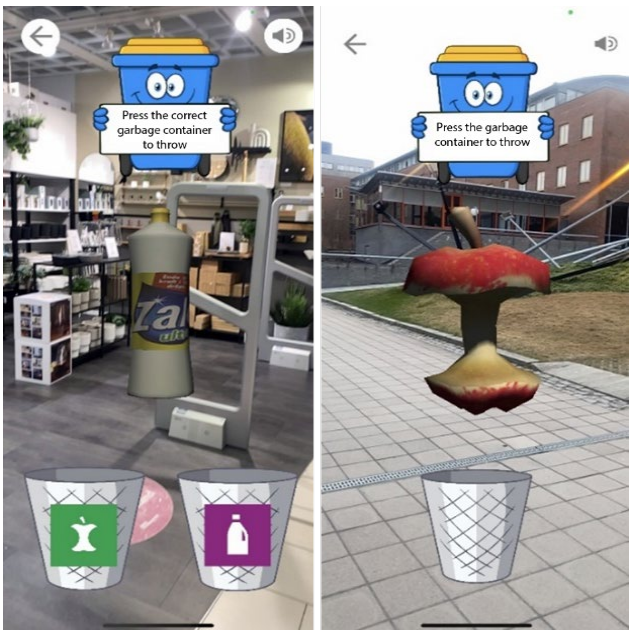

Figure 1. Example gameplay screenshots. Plastic garbage on medium difficulty (left). Food garbage on easy difficulty (right).

Q5, Q7, and Q9 (banded in Table 1), higher score is better. For questions Q2, Q4, Q6, Q8, and Q10 (non-banded in Table 1), lower score is better.

Question	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**
Mean	3.4	2.4	3.3	3.6	3.5
SD	0.48	0.99	0.66	0.99	0.87
Question	**Q6**	**Q7**	**Q8**	**Q9**	**Q10**
Mean	2.1	3.9	2.3	3.1	2.6
SD	0.60	0.33	0.83	1.05	1.22

Table 2. SUS Mean score and standard deviation (SD) for each question. Score range 1 to 5.

Regarding open-ended comments, a device with a larger screen (e.g., tablets) was suggested by several participants who reported difficulties when trying to observe objects in detail. Other participants also experienced glitches during testing and emphasized the need to resolve such issues before exposing the app to the target user group, to prevent irritation. One participant suggested to log failed sorting attempts and use this data to increase learning potential when sorting garbage. The same participant also

suggested to expand Sorterius and use it as a learning tool for sorting other item categories. Overall, participants gave positive comments of the general usability of the game.

4 DISCUSSION

The mobile app Sorterius show promising potential for being used by individuals with ID, and hopefully influence PA levels. Participants in this study believed people with ID would be able to learn how to use the app (Q7) and that they would use it regularly (Q1). However, one question (Q4) affected the overall score negatively, showing a high score for thinking the target group would need support to use the app. For this user group, relying on support from caretaker is common. Because of this, scoring high in this question may therefore not necessarily substantially affect the usability. In fact, engagement of support people may increase motivation for PA [6]. In the previous work by Haugland [12], this question was scored with a similar high SUS score. Haugland also implemented a Pokémon Go-inspired AR game. One possible explanation to this score, may be that people with ID can struggle with abstract concepts, and AR games may therefore be challenging for the target group.

There was also a large score difference between the individual with the highest score (SUS=80) and the individual with the lowest score (SUS=42.5). When completing the questionnaire, several participants indicated that it was difficult to generalize, because they worked with people with different levels of ID. Although one participant thought the app was usable for people with moderate to severe ID (with support), others thought that it would be too difficult for people with a moderate severity level. Variety in SUS-questionnaires is not unusual, but the SUS range was nonetheless wide in this usability test. This SUS-questionnaire may be hard to evaluate precisely without testing the app on the target user group.

This research has some limitations. The SUS questionnaire was translated to Norwegian and modified to target people working with ID. This could potentially affect the meaning of the questions. A validation of the SUS questionnaire in the Norwegian language is thus required as further research. In addition, due to the restrictions caused by the COVID-19 pandemic, we could not invite people from the actual target user group to test the app. These issues may affect the validity of results and have been specifically addressed in the ongoing pilot and feasibility study [9; 10].

5 CONCLUSION

The benefits of PA could also be achieved by people with ID. Using technology is one way to provide incentives to a target group outside the traditional marketing campaigns of technology development. The apps available in the market tend to be too complex for people with ID. This research has presented a tailored app aiming to motivate the target user group to do PA. The main contribution of this project is a cross-platform AR app combining a motivational tool for PA participation and learning (e.g., how to sort garbage), for a group that is often neglected in technology intervention in society. The app includes goal setting, involving the support people around the users with ID, which previously is shown to improve motivation towards PA in this user group. Future testing of the app should include users with ID to ensure the generalizability of this research and usability of the app. The evaluation of the test results shows that, although some of the test scores were low, we have created a “marginally acceptable” user interface for the targeted user group.
The developed solution can be expanded to target a broader range of users and projects. Using AR to address meaningful societal aspects, such as the environment, can be a helpful tool in raising awareness while at the same time strengthening the knowledge towards serious topics in an engaging digital environment. The final product has received exciting feedback from experts and testing participants.

Sorterius is currently being used in a pilot and feasibility study for a randomized control trial (RCT) intervention where one of the goals is to investigate whether tailored mHealth support can stimulate PA for individuals with ID [9; 10]. A Norwegian version is available in for free download in Apple’s AppStore [17] and in Google Play [18]. English, Portuguese, Italian, and Spanish versions are currently under development as part of the MOVE-IT project [19].

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