eHealth Approach for Motivating Physical Activities of People with Intellectual Disabilities

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Abstract. Compared with the general population, people with intellectual disabilities have worse health, lower levels of activity, and greater barriers to participating in fitness activities. Regular physical activity has positive effects on cardiovascular and psychosocial health and thus it is important to identify effective interventions for people with intellectual disabilities in everyday settings. In this position paper we present the design and development of prototypes of game-based eHealth solutions for behaviour change and health promotion by influencing physical activity. Participatory design and agile development have been applied in this project to deliver a system based on three solutions to promote, motivate and maintain physical activity in people with intellectual disabilities: Guided in-door bicycle exercise, guided out-door exercise and guided mild workouts. All the solutions provide virtual environments and motivation features adapted to people with intellectual disabilities for better engagement.

Keywords: Intellectual disability · eHealth · mHealth · Physical activity · Gamification

1 Introduction

Intellectual disabilities (IDs) are intellectual and functional impairments caused by a neurodevelopment disorder [1]. The prevalence of IDs ranges from 2 to more than 30 per 1,000 children [2], and the classification of IDs depends on the severity of the deficits in the adaptive behaviour (measured by the Intelligence Quotient – IQ). People with IDs are on an increased risk of health-related problems and their health needs are often unrecognized or unmet.

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Among the comorbidities of people with IDs, metabolic related diseases are the most prevalent [3], caused mainly by a significant lower physical activity and higher weight decompensations [4, 5]. Approximately 50% of people with IDs perform a sedentary life style and 40% has been found to do low physical activity [6]. A recent review found that only 9% of people with IDs worldwide achieved the WHO's minimum physical activity guidelines [7], despite meeting the physical activity guidelines was positively correlated with male gender, younger age, milder IDs, and living without supervised care. In the general population, a more sedentary lifestyle has be-come a pronounced problem in younger people [8], and it is a greater problem in youth with ID [9]. Low levels of physical activity could be due to barriers, such as scarcity of available resources and opportunities or a lack of motivation [10].

Physical activity is a modifiable risk factor for chronic diseases and an important way to improve health and prevent diseases [11]. Several studies have reported on the effects of physical activity interventions for people with ID on physical fit-ness indicators, such as balance, muscle strength, and quality of life [12]. Furthermore, a review found a moderate level of evidence that sport-related activities seem to contribute to well-being and perception of social competence [13]. A multi-component intervention in Sweden to improve diet and physical activity in individuals with ID in community residences showed positive effects on levels of physical activity and work routines [14]. However, only adults with mild to moderate IDs were included, and effect sizes were small. A recent theory-based randomised con-trolled study of adults with all types of ID did not find any significant increases in levels of physical activity (steps per day) [15]. Furthermore, the results of a recent cluster-randomised study of older adults in the Netherlands showed marginal effects and substantial missing data, despite being well prepared with a published protocol and using day-activity centres for the intervention [16].

Studies often include people with mild to moderate ID only, but the benefits for people with severe ID tend to be at least as good [14]. Motivational issues have been challenging, particularly for approaches oriented to sustain the effect after the intervention [13]. The main objective of the project *"Effects of physical activity with e-health support in people with intellectual disabilities"* is to enhance physical activity in youths and adults with IDs by means of motivational technology-based tools. As low physical activity is a determinant of health, and as increasing activity has positive effects on cardiovascular and psychosocial health, identifying effective interventions for use in everyday settings is of utmost importance. Studies conducted to increase physical activity in people with IDs are often non-randomised, in non-natural settings, and not theory-based and often exclude people with more severe IDs. Recent well-designed studies in this field have failed to demonstrate improved levels of physical activity in intervention groups. This paper describes the rationale and characteristics of three prototypes to support and motivate people with IDs to increase their physical activity.

2 Materials and Methods

The study will involve individuals with all types of ID who perform low activity levels, as this target group has been previously identified to have the greatest chances of improving the fitness condition [16]. A person-centred physical activity (PA) programme is expected to increase level of fitness, mental well-being and social support, and improve health conditions such as blood pressure and functional strength [17].

Although previous studies have been theory-based, the person-centred focus could improve with the use of individual goalsetting [18] and we have designed the intervention in a natural setting to enhance the effect [19]. Staff involvement will be central. We also expect the systematic use of e-health with rewards and gamification to be beneficial [20]. In Norway, many individuals with IDs have a smartphone they can use for tailored physical activity games, which has not been tested previously. Accelerometers have been used to examine physical activity and sedentary time patterns in related populations [21].

The project to which this position paper belongs defines three sub-objectives. First: to integrate theory with users' needs to design a motivational e-health support in natural settings. Second: to investigate the effects of this physical activity programme in youth and adults with ID in a randomised controlled trial. Third: to increase research activity and national and international cooperation in this little investigated field.

2.1 Technology-Based Motivation

The technical contribution of the research project *"Effects of physical activity with e-health support in people with intellectual disabilities"* shall be the development of tools that can contribute to increased physical activity. Given the user-centred approach, we aim to take advantages of that many people with IDs enjoy the use of new technologies and multimedia and thus give them access to virtual and real environment through recorded physical activity. We plan to develop several applications that are able to record physical activity and provide real-time motivational feedback. Recorded activity will then be swapped into time to watch movies and TV. We aim at studying different reward and motivation mechanisms from computer games and tailor them to people with IDs.

2.2 User Involvement from Early Stages

Users and user-organisations are involved in all parts of the project. To understand the users' needs and to design effective health behavioural support tools, we will gather data from focus groups and individual interviews. Participants will be selected strategically.

Two focus groups will consist of six to nine participants who will be asked to discuss their opinion regarding the role of technology and behaviour change support. Users, relatives, staff and professionals will be involved to design an optimal enjoyable programme for increasing physical activity [19]. We will use thematic analysis to summarize the results and extract user needs and perceptions.

We wish in the current project to go a step further than just gather user input at the start of the project, and use Participatory design (PD). More specifically, we will use workshops and think-aloud-protocols in our lab and out in the participants daily environment. We will conduct individual interviews with participants after the focus group discussion. Later, these participants will be invited to think aloud while interacting with our prototypes and reflecting its ability to meet their needs.

2.3 Mobile Technologies and Gamification for Motivating Behaviour Change

Despite the promise of mobile health (mHealth) and the explosion of fitness-related apps in markets, the vast majority of solutions are yet focused to a routine care basis and to record health and fitness-related data. Several studies have evaluated the effectiveness of mHealth interventions in specific clinical endpoints related to health promotion and disease worsening preventing [21]. Gamification and coaching techniques are also a promising feature of mobile health apps Sannino et al. [22] introduced the concept of a constant follow-up of the patient's performance along with continuous feedback and reward system according to the user behaviour and disease control.

In the scientific literature, there is a lack of work to create a rigorous process for design of mobile-based solutions for people with IDs targeting a behavioural shift. Giunti proposed a model based on User-Centred Design (UCD) [23] for the design of mHealth solutions for chronic patients using a compromise between medical knowledge, Behaviour Change Technologies and gamification. Schnall et al. explored the use of Information Systems Research (ISR) framework as guide for the design of mHealth apps [24] as a way to promote a change in the users. Jia et al. defined a design framework for self-management mHealth solutions employing the quantitative Fogg Behaviour Model to enhance user's execution ability [25]. Those work used several participatory researching techniques but both including adults and children. Although authors identified the participatory techniques used in their work, no information regarding what type of technology was determinant for promoting a behaviour change, which limits its reproducibility in the context of IDs. To the best of our knowledge, no study has proposed a methodological framework to design context-aware and personalised mHealth solutions to support and motivate people with IDs to increase physical activity habits.

3 Results

This innovative project results in a system composed of three different solutions which can co-exist and motivate people with IDs to increase physical activity on daily basis with the use of mobile phones, wearables and gamification strategies.

3.1 Used-Centred Design Requirements

The thematic workshops with experts, parents and institution staff leaded us to define the baseline requirements of the system. This information was exchanged on meetings and contact through emails in the start phase of the project, but also during implementation to discuss features and decisions. This cooperation has provided valuable information on how to develop a system for this kind of users when it comes to design, content, and layout. At the meeting, the ideas for this project were presented through illustrations of the design and explanations from the authors. The attendants of the meeting were then allowed to give their opinion on what they thought about the ideas. The meeting resulted in constructive input to the project and new features that could be included in the application. It was also motivating to see that the user representants were positive and interested in the project.

Table 1. Summary of the system requirements based on experts opinions.

Scope area	Requirement
Physical activity in people with ID	Critical factors for being physically active are the support from parents and care-takers, to be able to show someone what is achieved, predictability, coping ability of activity, amusing and fun, medals and rewards. It is necessary with a clear correlation between reward and activity
Intervention studies in people with ID	Few intervention studies with ID and E-health and struggles with dropouts and missing data in studies. However, the presenter is favourable to that mobile health apps interventions can provide a significant effect on improving PA levels
Motivation in people with ID	Inner (joyful, meaningful, coping, etc.) should be preferred over external motivation (praise, money, threats, etc.) to get a long-term effect. To achieve a behavioural change takes a structured plan, support from caregivers and much effort
User-friendly environment	It is important to achieve predictability and how the application should be able to express what is about to happen for an individual with ID or at least be helpful to do so. Use figures and icons to explain different activities and support audio

Table 1 summarizes the main requirements of the system based on the opinions of experts. Some of the critical remarks were that e-health should provide amusement, be a tool that can show others the achievements performed and provide rewards that are related to the performance in an activity. An e-health tool should be easy to use, but not childish as it can appear stereotypical and insult some users.

3.2 eHealth Based Proposed Solutions to Increase Physical Activity

Physical activity will be measured using the mobile phones in-built accelerometers, wristbands and a bike-roller for in-door static physical activity. This input will be the basis for the game. Our approach provides primary rewards mechanisms including fun and achievement elements. Social interaction has been identified as a powerful reward, so opportunities for collaborative missions are included.

The game needs to offer progressive mastery experiences, which again means that it will have to be tailored to the user. Care workers involved in the project helped to tailor the physical activity game to the individual' goals and resources and specifics of the intervention will be developed iteratively in close collaboration with users.

The system provides three main solutions: Guided in-door bicycle exercise for aerobic mild intensity exercise, which makes use of a tricycle and a bike-roller connected through Bluetooth to a tablet; an augmented-reality based game for out-door moderate exercising and a coaching app for promoting in-door workouts for moderate to hard exercises.

Proposed Solution #1: Guided In-Door Bicycle Exercise. The first solution comprises hardware and software modules to track and record the amount (intensity and time) of physical activity on indoor bikes. To this end, the solution can use two different bikes: (1) an outdoor bike mounted on a Tacx roller, and (2) an indoor, stationary exercise bicycle/ergometer bike. The goal is to detect the activity performed on the bike and transfer the activity measurement to a tablet-based entertainment system, which will react to the performance of the user in the bike and will show different multimedia records (real routes, virtual routes or media).

This solution will provide continuous feedback during realization of the physical activity. Therefore, the designed setup will monitor parameters such as speed, cadence and power. The setup is capable of transmitting data wirelessly (in the current prototype is Bluetooth LE) and in a real-time to a control unit (e.g. smartphone/tablet). The user is rewarded when selecting heavy load on the bike and for cycling for longer periods of time, proportionally. The graphical user interface contains computer game features connected to the hardware of the bicycle, so for example, by cycling through a landscape with computer game elements, receiving rewards in the form of symbols, animations, sounds, etc., during the exercise.

The first prototype uses a Tacx Flow Smart trainer (Upside left corner in Fig. 1) that support Bluetooth Low Energy and Ant+ connection. This trainer measures speed, cadence, and resistance; and it is possible to adjust the resistance on the power wheel. A cadence is a standard unit of measurement for bike trainers, and it means the frequency of the pedal turns when cycling. This trainer suits most type of bikes with a power wheel with a size between 26″ and 30″. For testing of the first solution during development, we borrowed a three-wheel bike from NAV, a welfare institution in Norway among other services provide equipment for those who have special needs (https://nav.no). Using a three-wheel bike is that it will appear steady and stable to ride.

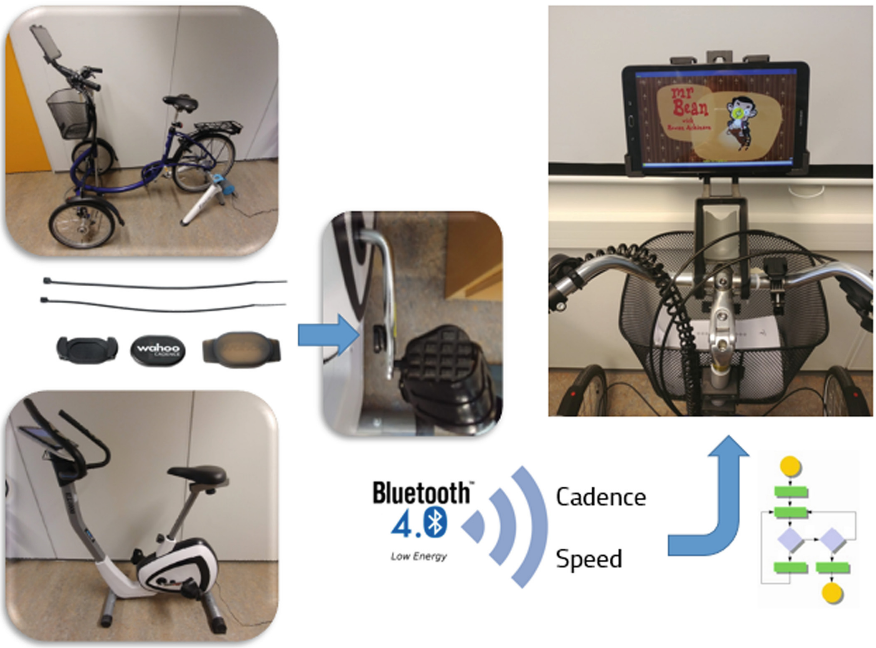

Fig. 1. Set up of the in-door bicycle based activity monitor.

The second prototype is mounted on an U.N.O. Fitness ET1000 (https://www.fitshop.no) ergometer bike (Down-left corner in Fig. 1). The bike comes with an embed computer that measures speed, resistance, and distance during a training session. To make the setup of the system more straightforward and scalable we decided to use a separate Wahoo cadence sensor which supports Bluetooth Low Energy (BLE) connectivity (central part in Fig. 1). The Wahoo sensor uses the FTMS protocol through BLE, the same as the Tacx Smart Flow trainer which makes the connection implementation simpler as it can be used in both solutions.

When the application starts (Upside-right corner in Fig. 1), a display showing the status of the current week activity time performed. From the start page, there is a navigation option to settings, video mode, game mode and history of activity. Video mode and game mode are the two options for activity sessions this system provides. After an activity session is finished, the activity time is added to the total activity time of the current week.

Proposed Solution #2: Guided Out-Door Exercise. The second solution provides a tool for people with intellectual disability to make them more physically active in mild to moderate intensities (walking and hiking). The technical solution is a mobile application that can be used anywhere and is tailored for a user group that previously have had no specially tailored solution with the same objective.

The app tacks the amount of physical activity in outdoor walking, hiking, etc. by means of step counters and GPS-tracking. This information is then transmitted to the entertainment system, which adapts the environment and reacts according to the pre-set preferences.

The gamification technique is based on augmented reality and proposes the user to chase virtual animals into a real environment (recorded with the mobile phone built-in camera). The user can select four different farm animals displayed through user-friendly avatars (Fig. 2), which will be distributed into the user surroundings, so they can walk towards the animal to 'collect' it.

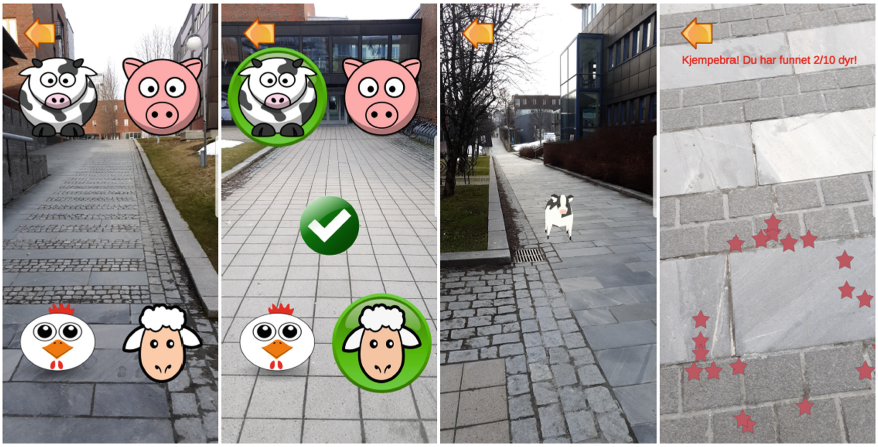

Fig. 2. Graphical user interface of the guided out-door exercise app.

Once the animal is collected, they will be prompted with a supportive message on the screen, and a voice recording encouraging and recognizing success. In addition, the screen has confetti bouncing on it, and a medal will be displayed containing the animal they reached. The setup is able to monitor parameters such as intensity, type of activity and time, and in future extensions it will transmit recorded data to a control unit/cloud-based application.

Proposed Solution #3: Guided Mild Workouts. The third solution provides a coach-based mobile application to promote physical activity in people with ID by means of a three-dimension avatar. This virtual character is customizable so that each user can make it look like he/she wants, so that connection between the user and the character may lead to higher levels of engagement and them wanting to use and interact with it. Once the avatar is created and customized, the app provides a set of basic workouts and pre-set combinations of them, so the user can choose to perform specific or complete routines.

When selecting an activity, the user interface shows the activity animation to make it clear to the user what it entails (Fig. 3). This is because it can be difficult to explain an exercise activity without any type of movement. Text To Speech features are also included in the app, to help the users understand context and functionality of the app which can otherwise be hard to convey using only the visual user interface. The app includes reminders by means of notifications to sustain the adherence to work out routines in case of periods of inactivity.

Fig. 3. Screenshots of the guided workouts app and the avatar.

4 Discussion

E-health provides a wide range of possibilities for monitoring and motivating people in the self-management of chronic illnesses. In this position paper we present the design and development of prototypes of game-based eHealth solutions for behaviour change and health promotion by influencing physical activity. Motion sensor games have been explored and found to be promising in people with ID.

Our approach to move out of the lab and into actual use included a first stage for meeting user's needs. Participatory design and agile development have been applied in this project to deliver a system based on three solutions to promote, motivate and maintain physical activity in people with IDs. These solutions may contribute to the physical activity of the user group of individuals with intellectual disability and also act as ring effect their physical and mental health, as well as improving their health and lifestyle situation. Once these applications have been assessed and improved in beta-tests, they will be used into a randomized-control trial to assess the effect of eHealth in direct physical activity indicators and secondary health endpoints.

References

1. van Schrojenstein Lantman-de Valk, H.M.J., Walsh, P.N.: Managing health problems in people with intellectual disabilities. BMJ **337** (2008). https://doi.org/10.1136/bmj.a2507
2. Boat, T., Wu, J.: Clinical characteristics of intellectual disabilities (2015). https://doi.org/10.17226/21780

3. Carey, I.M., et al.: Health characteristics and consultation patterns of people with intellectual disability: a cross-sectional database study in English general practice. Br. J. Gen. Pract. **66**, e264–e270 (2016)
4. Evans, E., Howlett, S., Kremser, T., Simpson, J., Kayess, R., Trollor, J.: Service development for intellectual disability mental health: a human rights approach. J. Intellect. Disabil. Res. **56**, 1098–1109 (2012). https://doi.org/10.1111/j.1365-2788.2012.01636.x
5. Hilgenkamp, T.I., van Wijck, R., Evenhuis, H.M.: Low physical fitness levels in older adults with ID: results of the HA-ID study. Res. Dev. Disabil. **33**, 1048–1058 (2012). https://doi.org/10.1016/j.ridd.2012.01.013
6. Haveman, M., et al.: Ageing and health status in adults with intellectual disabilities: results of the European POMONA II study. J. Intellect. Dev. Disabil. **36**, 49–60 (2011). https://doi.org/10.3109/13668250.2010.549464
7. Dairo, Y.M., Collett, J., Dawes, H., Oskrochi, G.R.: Physical activity levels in adults with intellectual disabilities: a systematic review. Prev. Med. Rep. **4**, 209–219 (2016). https://doi.org/10.1016/j.pmedr.2016.06.008
8. Winther, A., et al.: The Tromso Study: Fit Futures: a study of Norwegian adolescents' lifestyle and bone health. Arch. Osteoporos. **9**, 185 (2014). https://doi.org/10.1007/s11657-014-0185-0
9. Wallen, E.F., Mullersdorf, M., Christensson, K., Malm, G., Ekblom, O., Marcus, C.: High prevalence of cardio-metabolic risk factors among adolescents with intellectual disability. Acta Paediatr. **98**, 853–859 (2009). https://doi.org/10.1111/j.1651-2227.2008.01197.x
10. Howie, E.K., Barnes, T.L., McDermott, S., Mann, J.R., Clarkson, J., Meriwether, R.A.: Availability of physical activity resources in the environment for adults with intellectual disabilities. Disabil. Health J. **5**, 41–48 (2012). https://doi.org/10.1016/j.dhjo.2011.09.004
11. Elinder, L.S., Bergstrom, H., Hagberg, J., Wihlman, U., Hagstromer, M.: Promoting a healthy diet and physical activity in adults with intellectual disabilities living in community residences: design and evaluation of a cluster-randomized intervention. BMC Public Health **10**, 761 (2010). https://doi.org/10.1186/1471-2458-10-761
12. Shields, N., Taylor, N.F., Wee, E., Wollersheim, D., O'Shea, S.D., Fernhall, B.: A community-based strength training programme increases muscle strength and physical activity in young people with Down syndrome: a randomised controlled trial. Res. Dev. Disabil. **34**, 4385–4394 (2013). https://doi.org/10.1016/j.ridd.2013.09.022
13. Hutzler, Y., Korsensky, O.: Motivational correlates of physical activity in persons with an intellectual disability: a systematic literature review. J. Intellect. Disabil. Res. **54**, 767–786 (2010). https://doi.org/10.1111/j.1365-2788.2010.01313.x
14. Bergstrom, H., Hagstromer, M., Hagberg, J., Elinder, L.S.: A multi-component universal intervention to improve diet and physical activity among adults with intellectual disabilities in community residences: a cluster randomised controlled trial. Res. Dev. Disabil. **34**, 3847–3857 (2013). https://doi.org/10.1016/j.ridd.2013.07.019
15. Melville, C.A., et al.: Effectiveness of a walking programme to support adults with intellectual disabilities to increase physical activity: walk well cluster-randomised controlled trial. Int. J. Behav. Nutr. Phys. Act. **12**, 125 (2015). https://doi.org/10.1186/s12966-015-0290-5
16. van Schijndel-Speet, M., Evenhuis, H.M., van Wijck, R., van Montfort, K.C., Echteld, M.A.: A structured physical activity and fitness programme for older adults with intellectual disabilities: results of a cluster-randomised clinical trial. J. Intellect. Disabil. Res. **61**, 16–29 (2017). https://doi.org/10.1111/jir.12267
17. McConkey, R., Collins, S.: Using personal goal setting to promote the social inclusion of people with intellectual disability living in supported accommodation. J. Intellect. Disabil. Res. **54**, 135–143 (2010). https://doi.org/10.1111/j.1365-2788.2009.01224.x

18. Dixon-Ibarra, A., Driver, S., Vanderbom, K., Humphries, K.: Understanding physical activity in the group home setting: a qualitative inquiry. Disabil. Rehabil. **39**, 653–662 (2017)
19. Taylor, M.J., Taylor, D., Gamboa, P., Vlaev, I., Darzi, A.: Using motion-sensor games to encourage physical activity for adults with intellectual disability. Stud. Health Technol. Inform. **220**, 417–423 (2016)
20. Izquierdo-Gomez, R., et al.: Objective assessment of sedentary time and physical activity throughout the week in adolescents with Down syndrome. The UP&DOWN study. Res. Dev. Disabil. **35**, 482–489 (2014)
21. Marcolino, M.S., Oliveira, J.A.Q., D'Agostino, M., Ribeiro, A.L., Alkmim, M.B.M., Novillo-Ortiz, D.: The impact of mHealth interventions: systematic review of systematic reviews. JMIR mHealth uHealth. **6**, e23 (2018). https://doi.org/10.2196/mhealth.8873
22. Sannino, G., Forastiere, M., De Pietro, G.: A wellness mobile application for smart health: pilot study design and results. Sensors **17**, 611 (2017). https://doi.org/10.3390/s17030611
23. Giunti, G.: 3MD for chronic conditions, a model for motivational mHealth design: embedded case study. JMIR Serious Games **6** (2018). https://doi.org/10.2196/11631
24. Schnall, R., et al.: A user-centered model for designing consumer mobile health (mHealth) applications (apps). J. Biomed. Inform. **60**, 243–251 (2016). https://doi.org/10.1016/j.jbi.2016.02.002
25. Jia, G., et al.: A framework design for the mHealth system for self-management promotion. Bio-Med. Mater. Eng. **26**, 1731–1740 (2015). https://doi.org/10.3233/BME-151473