Rehabilitation through Accessible Mobile Gaming and Wearable Sensors

Dragan Ahmetovic
Antonio Pugliese
Sergio Mascetti
dragan.ahmetovic@unimi.it
antonio.pugliese@studenti.unimi.it
sergio.mascetti@unimi.it
Università degli Studi di Milano, Italy

Valentina Begnozzi
Elena Boccalandro
valentinabegnozzi@gmail.com
boccalandro.elena@gmail.com
Centro Emofilia e Trombosi Angelo Bianchi Bonomi, Fondazione IRCCS Ca' Granda, Ospedale Maggiore Policlinico di Milano, Italy

Roberta Gualtierotti
Flora Peyvandi
roberta.gualtierotti@unimi.it
flora.peyvandi@unimi.it
Università degli Studi di Milano, Italy
Centro Emofilia e Trombosi Angelo Bianchi Bonomi, Fondazione IRCCS Ca' Granda, Ospedale Maggiore Policlinico di Milano, Italy

ABSTRACT

Play Access is an Android assistive technology that replaces touchscreen interaction with alternative interfaces, enabling people with upper extremity impairments to access mobile games, and providing alternative means of playing mobile games for all. We demonstrate the use of Play Access to support physical therapy for children with haemophilia, with the goal of preventing long-term mobility impairments. To achieve this, we modified Play Access to enable the use of body movements, recognized using wearable sensors, as an alternative interface for playing games. This way, Play Access makes it possible to use existing Android games as exergames, hence better targeting patients interest.

CCS CONCEPTS

• **Applied computing** → *Health informatics*; • **Human-centered computing** → *Accessibility systems and tools*.

KEYWORDS

Rehabilitation; Physical therapy; Interaction substitution.

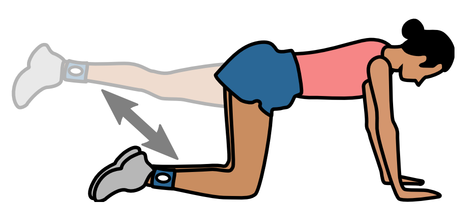
ACM Reference Format:
Dragan Ahmetovic, Antonio Pugliese, Sergio Mascetti, Valentina Begnozzi, Elena Boccalandro, Roberta Gualtierotti, and Flora Peyvandi. 2021. Rehabilitation through Accessible Mobile Gaming and Wearable Sensors. In *The 23rd International ACM SIGACCESS Conference on Computers and Accessibility (ASSETS '21), October 18–22, 2021, Virtual Event, USA.* ACM, New York, NY, USA, 4 pages. https://doi.org/10.1145/3441852.3476544

1 INTRODUCTION

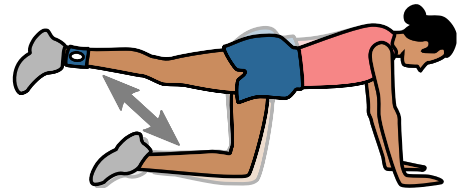
For people with haemophilia, hemarthrosis (*i.e.*, bleeding into joints) is a common condition [12], and one of the major causes of mobility impairment and disability [18]. Prior works highlight that physical exercise strengthens muscles, ligaments and tendons, improving the motion range of joints and preventing further articular damage due to recurrent hemarthrosis [9]. However, people with haemophilia are less physically active in comparison to their peers [17], and the COVID-19 pandemic has further reduced their exercise routine [8, 13]. In particular, maintaining adherence to training regimen was shown to be difficult for children [7, 10, 16].

As a means of promoting at-home exercises, prior works propose telerehabilitation [5] through exergames [4, 6]. However, designing effective exergames for children with haemophilia is challenging. The exercises need to be suitable for different patients' conditions [14], and the games need to be age-appropriate, engaging [11], and sufficiently numerous, so that, when a patient gets bored with a game, a different one can be used. It is also important to verify that the exercises are performed correctly, in particular during autonomous usage without a clinical supervisor [15].

To address these challenges, we propose to use existing popular mobile games as exergames, played using body movements suitable for physical therapy by children with haemophilia. To achieve this, we extended *Play Access* [3], a system designed to replace touchscreen interaction with different interfaces, to enable interaction with the games through body movements, detected with wearable sensors. For example, extending a leg (Figure 1) can be configured to trigger a tap on the screen at a given position, making Mario jump in the Super Mario Run [1] game (Figure 2(e)).



(a) Position 1 - Kneeling

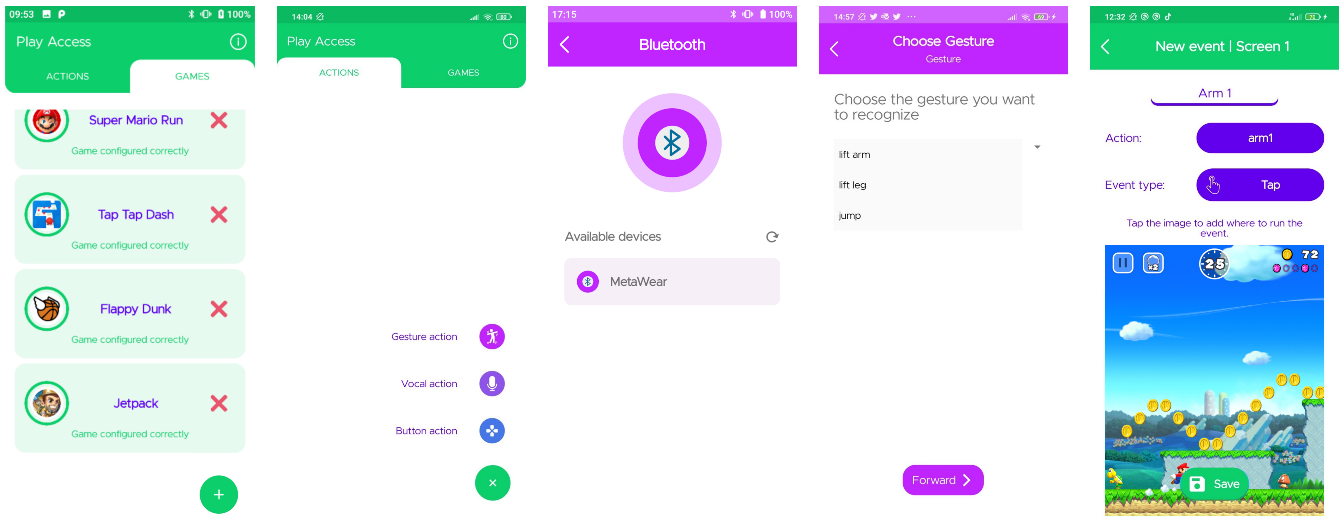


(b) Position 1 - Leg extension

Figure 1: Leg exercise detected using a wearable sensor

ASSETS '21, October 18–22, 2021, Virtual Event, USA

ACM ISBN 978-1-4503-8306-6/21/10.
https://doi.org/10.1145/3441852.3476544



(a) Game configurations (b) Triggering actions (c) Pairing Device and Sensor (d) Gesture selection (e) Event configuration

Figure 2: *Play Access* configuration screens

Input body movements are defined separately for every patient, in agreement with physical therapists, thus ensuring their appropriateness for the rehabilitation goals of each patient. Correct body movements need to be performed in order to play. Thus, the patient is stimulated to exercise appropriately. It is also possible to remotely collect interaction data between the patient and the games [2], enabling clinicians to analyze their adherence to the exercise regimen and their performance. The *Play Access* system will be tested by participants (children with haemophilia) enrolled at the "Angelo Bianchi Bonomi" Hemophilia and Thrombosis center in Milan, Italy.

2 PHYSICAL THERAPY WITH *PLAY ACCESS*

Play Access is an *interaction substitution method* for replacing touchscreen interaction with different interfaces. It is implemented on Android as an Accessibility Service (Figure 2), running in the background and simulating touchscreen events when specific triggering actions are entered on alternative interfaces. It is published on Google Play Store[1], and its source code is available online[2].

Play Access was first designed for people with upper extremity impairments [3], to access mobile games through personalizable interaction configurations, also adapting to changes in user abilities. In a new prototype, the system was modified to recognize body movements through wearable sensors and use them as input for playing games. Thus, any mobile game can be used as an exergame, supporting physical therapy in children with haemophilia. *Play Access* presents three features fundamental for this goal.

2.1 Ability to Interact with Popular Games

Play Access allows to play existing Android games, including popular ones (Figure 2(a)), by simulating touchscreen interactions anywhere on the screen. Configured games can be easily replaced with new ones if children get bored. This way, it is easier to stimulate children to do exercises and stick to the training regimen.

Play Access relies on the user to manually label interface elements used to play on a screenshot of the game (Figure 2(e)). For the labeled elements the user can then specify the touchscreen *interaction events* to perform (*e.g.*, a tap), and the *triggering actions* required to activate them (*e.g.*, leg extension).

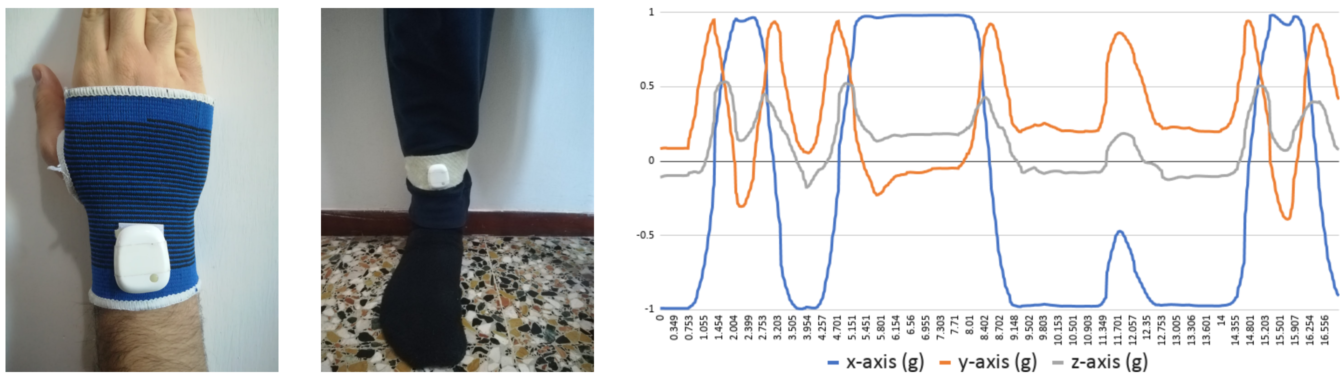
2.2 Custom Exercises for Each Patient

Triggering actions used to replace default touchscreen interactions are specific to each user. They are defined for every target game and each game allows multiple configurations, adapting to user abilities, context and preferences. External switches and voice input were already available as alternative interfaces and body gestures were added in the new prototype (Figure 2(b)). Body gestures (Figure 1) are detected using wearable Bluetooth inertial sensors (Figure 3). Connected sensors can be selected in the app (Figure 2(c)), and set to recognize specific body movements. These movements, used as triggering actions, are decided by clinicians, based on patients' physical conditions and the rehabilitation goal. In the current version of the system, physical therapists, who are also authors of this paper, have defined a number of different body movements suitable to be used for exercises, which can be selected as triggering actions (Figure 2(d)). In future, we will integrate a recording functionality to enable customization for every body gesture.

2.3 Telerehabilitation & Remote Data Logging

Play Access records user interactions and triggering actions, which are transmitted to a remote server [2]. In particular, considering body gesture input, we are able to collect inertial data recorded by the wearable Bluetooth sensors (Figure 3(c)). This allows clinicians to assess whether the patients are actually doing rehabilitation and whether they are performing the movements correctly.

[1]https://play.google.com/store/apps/details?id=com.carlo.a_cube
[2]https://github.com/A-CubeTest/A-Cube



(a) Sensor on hand (b) Sensor on leg (c) Sensor data

Figure 3: Wearable sensors and sensor data

It is also possible to assess which games are commonly played, which replacement interfaces are most frequently used, and to verify whether different triggering actions are recognized correctly. For example we can check if the system is able to recognize body movements confidently or if there is possible confusion between different recorded inputs.

3 PRELIMINARY EXPERIMENT & RESULTS

We deployed *Play Access*, adapted for use with body gestures, at the Hemophilia and Thrombosis center "Angelo Bianchi Bonomi" in Milan, Italy. The system is ready to be tested by physical therapists with children with haemophilia to assess its acceptance and appreciation by the users, to understand which games are more appropriate for the rehabilitation goal, and which body gestures are most suitable and can be efficiently applied for mobile games.

Preliminary results of an initial informal trial with one participant suggest that the choice of the games, gestures and their combinations is critical for the successful use of the system for telerehabilitation. Specifically, it is important to identify games having compatible interactions with the exercised body movements, in terms of interaction speed and required reaction time. Erroneous combinations of games and gestures can make the game too easy or too hard to play, and the inability to play successfully could demotivate the user, leading to the abandonment of the training regimen.

4 CONCLUSIONS & FUTURE WORK

We demonstrate the use of *Play Access* system as a support for telerehabilitation of children with haemophilia. Our approach, implemented as an Android Accessibility Service, allows to replace touchscreen interactions with different interfaces, including personalized body movements, detected through wearable Bluetooth inertial sensors. Thus, *Play Access* can transform existing mobile games into full-fledged exergames. The usage of popular mobile games is meant to engage children, improving adherence to the training regimen and discouraging abandonment. At the same time, remote data collection can help clinicians to support patients remotely, verifying if the exercises are performed correctly.

As future work, we will define a methodology to drive the selection of games suitable for the body movements to exercise. We will also investigate whether wearable sensors can be replaced by computer vision body pose detection, as a means of recognizing body movements. This way, it will be possible to recognize a wider range of movements, that would otherwise require multiple sensors to be detected, and the users will just need their mobile phone in order to exercise. Furthermore, we intend to apply the same gamification approach to other applicative domains, including speech rehabilitation, for example by defining specific vocal exercises and use them to control mobile games.

REFERENCES

[1] 2021. Super Mario Run on Android Play Store. https://play.google.com/store/apps/details?id=com.nintendo.zara
[2] Dragan Ahmetovic, Cristian Bernareggi, Mattia Ducci, Andrea Gerino, and Sergio Mascetti. 2021. Remote Usage Data Collection and Analysis for Mobile Accessibility Applications. In *International Conference on Pervasive Computing and Communications (PerCom) - Mobile and Pervasive Assistive Technologies Workshop (MPAT)*. IEEE.
[3] Dragan Ahmetovic, Daniele Riboli, Cristian Bernareggi, and Sergio Mascetti. 2021. RePlay: Touchscreen Interaction Substitution Method for Accessible Gaming. In *International Conference on Human Computer Interaction with Mobile Devices and Services*. ACM.
[4] Elena Anna Boccalandro, Valentina Begnozzi, and Pier Mannuccio Mannucci. 2020. Intelligent game engines for home exercises (exergames) in boys with haemophilia. *Haemophilia* (2020).
[5] Elena A Boccalandro, Giuseppe Dallari, and Pier Mannuccio Mannucci. 2019. Telemedicine and telerehabilitation: current and forthcoming applications in haemophilia. *Blood Transfusion* (2019).
[6] Nunzio Alberto Borghese. 2017. Exergaming for Autonomous Rehabilitation. In *Mathematical and Theoretical Neuroscience*. Springer.
[7] Nailah Coleman, Blaise A Nemeth, and Claire MA LeBlanc. 2018. Increasing wellness through physical activity in children with chronic disease and disability. *Current sports medicine reports* (2018).
[8] Hortensia De la Corte-Rodriguez, M Teresa Alvarez-Roman, E Carlos Rodriguez-Merchan, and Víctor Jimenez-Yuste. 2020. What COVID-19 can mean for people with hemophilia beyond the infection risk. *Expert Review of Hematology* (2020).
[9] S Harris and LN Boggio. 2006. Exercise may decrease further destruction in the adult haemophilic joint. *Haemophilia* (2006).
[10] Christopher J Holt, Carly D McKay, Linda K Truong, Christina Y Le, Douglas P Gross, and Jackie L Whittaker. 2020. Sticking to It: A Scoping Review of Adherence to Exercise Therapy Interventions in Children and Adolescents With Musculoskeletal Conditions. *Journal of orthopaedic & sports physical therapy* (2020).
[11] Seungmin Lee, Wonkyung Kim, Taiwoo Park, and Wei Peng. 2017. The psychological effects of playing exergames: A systematic review. *Cyberpsychology, Behavior, and Social Networking* (2017).

[12] Matthew Lombardi and Alfonso C Cardenas. 2018. Hemarthrosis. (2018).
[13] Álvarez Román MT, I de la Plaza Collazo, H De la Corte Rodríguez, Romero Garrido JA, Rivas Pollmar MI, T Cebanu, E González-Zorrilla, P Acuña, EC Merchán, Blanco Bañares MJ, et al. 2020. Registry of patients with congenital bleeding and COVID-19 in madrid. *Haemophilia* (2020).
[14] Claude Negrier, Axel Seuser, Angela Forsyth, Sébastien Lobet, Adolfo Llinas, M Rosas, and Lily Heijnen. 2013. The benefits of exercise for patients with haemophilia and recommendations for safe and effective physical activity. *Haemophilia* (2013).
[15] Ana Pereira, Duarte Folgado, Francisco Nunes, João Almeida, and Inês Sousa. 2019. Using Inertial Sensors to Evaluate Exercise Correctness in Electromyography-based Home Rehabilitation Systems. In *International Symposium on Medical Measurements and Applications*. IEEE.
[16] P Petrini and A Seuser. 2009. Haemophilia care in adolescents–compliance and lifestyle issues. *Haemophilia* (2009).
[17] Ana Jéssica Pinto, David W Dunstan, Neville Owen, Eloisa Bonfá, and Bruno Gualano. 2020. Combating physical inactivity during the COVID-19 pandemic. *Nature Reviews Rheumatology* (2020).
[18] E Carlos Rodríguez-Merchán. 1997. Pathogenesis, early diagnosis, and prophylaxis for chronic hemophilic synovitis. *Clinical orthopaedics and related research* (1997).