

Integration of exergaming in pediatric rehabilitation

Bruno Bonnechère

REVAL Rehabilitation Research Center – Faculty of Rehabilitation Sciences, Hasselt University, Diepenbeek, Belgium

Bruno.bonnechere@uhasselt.be

Keywords

Pediatric rehabilitation; exergames; video games; new technology; motivation

Abstract

The development and generalization of modern technology have totally modified our world and habits. Concerning rehabilitation, the situation is a bit different and the integration of technology seems to be a bit slower than in other fields. The development of video games, and in particular active video games, offers new perspectives and pediatric rehabilitation. In this paper, we present the different technologies currently tested and developed in various rehabilitation contexts ranging from neurological rehabilitation (children with cerebral palsy) to pain management but also diseases such as autism spectrum disorders. Finally, we discuss the current and future challenges related to the integration of exergames in pediatric rehabilitation and propose some solutions to promote the development and implementation of these solutions on a large scale in clinics.

Introduction

Currently, informatics and technology are everywhere, or almost everywhere, in our lives. In the last decade, not only technology has developed drastically but two other elements are also of importance for the development and implementation of innovative solutions, at a large scale, in the healthcare sector: the democratization of the technology and the miniaturization of the devices. The development of new technology offers, therefore, a lot of new opportunities in rehabilitation for both the diagnosis, the assessment, and the treatment.

In this paper, we are going to focus on the use and development of exergames in pediatric rehabilitation but the readers should be aware that the use of technology is much broader than this particular set of applications.

Before discussing more in detail the exergames let's briefly discussed some key potential advantages of the integration of new technology in rehabilitation.

The first one is related to the lack of access to physical rehabilitation centers. Lack of access to healthcare facilities or healthcare professionals has been pointed out by the WHO as one of the major obstacles to the rehabilitation process not only in low-income countries but also in high-income countries (1). Recently the problem of accessibility and physical interaction with clinicians has been brought to the forefront in the context of the COVID-19 crisis (2). The use of technology could help to partially solve the issue related to the accessibility of care with the development and generalization of telerehabilitation and teleconsultation (3).

Another important point, especially for pediatric rehabilitation, is the motivation of the patients. The motivation of the patients is the main key to an as successful as possible rehabilitation treatment (4). The main challenge is therefore to keep patients motivated enough despite the feeling he/she could have of *'inefficiency'*, *'lack of progress'*, *'tiredness'*, etc. Such problems are even more present with teenagers during the puberty identity crisis. By definition games are fun and induced distraction thus the patients are more motivated by this kind of exercise (at least at the beginning of the treatment we will discuss this point later on) (5).

A last potential advantage is that, in most cases, the exercises and the motions performed by the patients can be recorded. This information can be used later on to provide real-time feedback to the patients to correct him when he is performing the exercises, or to remind him to do the exercises or how to do them properly (6,7). This information can also be used by the clinicians to follow the evolution of the patients and, if needed, adapt the rehabilitation program or the difficulty of the exercises to the real need and specificity of the patients (8,9). By doing so the treatment is always adapted to the patients and thus the quality of the care is increased.

Definitions

There are a lot of different terms used to describe the development and use of games in rehabilitation (both motor and cognitive aspects). Unfortunately, these terms are often misused which could lead to a certain confusion for the clinicians. Therefore before discussing the clinical aspect of this new domain it is important to define the different terms used in the literature.

Clinical applications

Different research directions (e.g., motor rehabilitation, cognitive rehabilitation, pain management) are currently under development or already in clinical use. We will present here the results and level of evidence for some of the most important, or most promising field, of pediatric rehabilitation. We try to give the best possible overview of the possibilities offered by the addition of games in the rehabilitation but could not present all the different studies. First, we will present applications where the games are used to promote motor functions: for neurologic rehabilitation and solution to promote physical activity levels. Then we will discuss other fields of applications where the games are more used to stimulate cognitive functions.

Cerebral palsy

For the sake of this presentation, we focus on children with cerebral palsy but the principle can be easily transferred to other neurologic or orthopedic pathologies since most of the solutions are focusing on balance and mobility issues.

Cerebral palsy is a group of movement disorders that appears in early childhood. It is due to brain lesions occurring during pregnancy, childbirth, or during the first year of the children. These lesions, and therefore the movement disorders, are irreversible because they occurred in immature brain tissues. Patients suffering from cerebral palsy present various motor and balance troubles.

In a systematic review about the use of commercial video games in rehabilitation, we found that the integration of this kind of game in the treatment of children with cerebral palsy was quite popular (after balance issue related to aging and stroke) (10). Other important findings of this review are that the exergames increase patients' motivation and that the patients are performing more repetitions of the exercises than during conventional rehabilitation sessions. The latter is particularly important since it is well known that the number of repetitions is a key factor in rehabilitation (11).

The results of 19 RCTs on the efficacy of exergames on upper extremity function, ambulation, and postural control were summarized in a meta-analysis (12). 12 of the 19 studies were done using commercial solutions, among them the great majority were done using the Nintendo Wii (8/12).

13 RCT studies were included measuring arm function. Across all studies, there was a strong effect ($d = 0.835$; 95% CI = 0.388–1.282) in favor of the intervention. Interestingly the authors observed a large difference in the effect between exergames specially developed for the rehabilitation and commercial systems ($d = 2.162$ for specific systems; $d = 0.491$ for commercially available systems). Concerning the ambulation, 8 studies were included. The overall effect size was 0.755 (95% CI = 0.348–1.161), indicating a medium to large effect size, due to the small sample size the authors were not able to perform subgroups analysis to compare specific and commercial solutions. Finally, for the postural control, 10 studies were included. The overall effect size was 1.003 (95% CI = 0.503–1.502), indicating a large effect size.

Physical activity

Overweight and obesity issues are a huge and growing healthcare challenge worldwide and this problem is becoming more and more precocious. The 'traditional' video games (i.e., video games controlled with a controller when the player is seated), also called passive video games, are known to increase the level of sedentariness and promote snacking and junk food (13). To try to change this negative image and promote physical activity games companies developed systems (mainly Nintendo Wii™ and Microsoft Xbox Kinect™) where the players have to move to control the games: the active video games.

The first question is to determine whether or not active video games induce an increase in energy expenditure and if yes what is the level of physical activity reached during this kind of training. Many studies have been conducted in this field. The level of energy expenditure reached is estimated to be between 2.7 and 5.4 metabolic equivalents (i.e. moderate-intensity level of physical activity) when children and teenagers playing active games (14). A study compared the levels of energy expenditure in an obese population and in a control group, surprisingly the author found that obese children lose fewer calories than the control group (15). Although the levels of energy expenditure reached are relatively low the next question is to determine if active video games could still be successfully integrated into the management of obesity and overweight. A large study was conducted with 171 obese students included. They were separated into 2 groups: 63 people were included in the group playing video games and the other 108 in the control group. After nine weeks of training, the level of physical activity was higher in the intervention group and patients had lost between 1.5 and 2kg after this intervention compared to the control group (16).

There are also plenty of different solutions developed to provide dietetic information, records the food consumed, and modify eating behavior (17).

Autism spectrum disorders

Autism spectrum disorders are developmental conditions that involve difficulties in social and non-verbal interaction, speech, and restricted or repetitive behavior. Exergames could also be used with patients with autism spectrum disorders in order to reduce fear, anxiety level, and to increase social skills (18). The development of specific solutions for patients with autism spectrum disorders is a growing field. The idea is to immerse the patients in a virtual environment where they can learn to collaborate and interact with other players without fearing the interactions (19). Another potential advantage for the clinicians is that when the patients are immersed in the games they are paying less attention to their real environment and the clinicians can touch them to promote proprioception and acceptance of others (20). The last important area of research in the development of diagnosis tools, autism may be difficult to diagnose, especially in young children. The way the children are playing and using tablets may be used to distinguish affected from not affected children and to assess the severity of the disease (21).

Pain management

Pain is one of the most frequent symptoms in rehabilitation, and also one of the most complex to manage. Several approaches can be used to integrate exergames in pain management programs.

Pain, especially chronic pain, remains a relatively poor and poorly understood process. Therefore patients may have a lot of questions related to it. Healthcare professionals are not always present and available to respond. Thus have been developed (explanatory videos, texts, videos) to answer the questions of the patients and help them. These virtual systems have proven their efficacy in the treatment of chronic pain (22). Therefore, such kind of tools appears to be a

feasible solution to increase the dialogue on pain management between patient and therapist (23). However, currently, most of the studies using such kinds of interventions are done with adults, not with children.

A second approach is to create a distraction phenomenon in patients when performing painful procedures. The challenge for developers is to create games in which the patients won't move but will be immersed enough in order to not feel pain. Such solutions have been developed for young children going to the dentist. There was a significant decrease in pain perception and anxiety with the use of virtual reality glasses and games during dental treatment (24).

Another particularly painful condition is the treatment of severe burns. Virtual reality and serious games can be used to reduce pain during wound cleaning. The results seem to be maintained over time: 3 or 4 days after the intervention the results are maintained and the pain is still decreased during care (25).

Adherence to medical treatment

We have seen that for pain management solutions have been developed to inform the patients. We know that treatment adherence is better when the patients are well informed about their pathologies and treatment. This is particularly important in pediatric rehabilitation.

One salient aspect of the exergames is that pieces of advice and medical information can be added to games. The first example of such kind of games was a game for diabetic children developed in collaboration with gaming and pharmaceutical companies. A study shows that compared to a control group, children who play the games managed better their diabetes: the number of children who have to go to the hospital due to a glucose crisis decreased by 77% in the intervention group compared to the control (26). Another very popular game that had a significant impact on health-related behavior is "game. This game was created for children with cancer to teach them how to deal with cancer treatment (mainly chemotherapy) to maximize treatment adherence. In this game, patients must shoot cancer cells to fight the infections and manage clinical signs and adverse effects (e.g., constipation, nausea, etc.). A clinical trial has been done to compare the effect of the game compared to a commercial game in adolescents and young adults who were undergoing cancer therapy. Results showed that patients playing ' significantly improved treatment adherence, indicators of cancer-related self-efficacy, and knowledge about the disease (27).

Challenges to solve

Although exergames are being tested for several years in clinics there are still a lot of problems to solve before they can be broadly used in daily clinics. Some of these issues are related to the technology (i.e., price, accessibility, ease of use), but most of them concern the clinicians and the patients: people must still be convinced that exergames are serious tools for rehabilitation and not just fun. Large scale RCTs are needed to determine whether or not exergames can be used in pediatric rehabilitation and to what extent. One of the limitations of the current studies is the relatively small sample size and an important heterogeneity in the patients but also in the tests used to evaluate the intervention, making the comparison between studies more complicated.

Besides the validation of the new interventions, other questions should be answered.

The first one is the long term motivation and/or long term efficacy of such kind of intervention. Most of the studies are relatively short (max 3 months of interventions) and the evaluations are performed after the intervention. There is not much information about the persistence of the benefit. Concerning the motivation and the treatment adherence, it has been demonstrated that in the beginning when you introduce novelty in the treatment the patients are motivated but this effect fades over time (28).

Another important point is to evaluate the mechanism of action of the exergames. This should be used to increase the quality of the rehabilitation and also to convince the most skeptical. A recent scoping review focusing on children with cerebral palsy suggested some possible mechanisms of action. For the motor skills, exergames enhanced problem-solving and cognitive engagement during play and increased motivation and neuroplasticity changes; exergames also created repetitive task-oriented and task-specific practices in an ecologically valid virtual environment that was similar to the real world and provided the flexibility of adjusting task difficulties, visual and/

or auditory feedback, and the potential of social play and interaction; and finally exergames offered social support from parents, peers, or therapists (29).

The safety of the intervention also needs to be further assessed, especially in the context of telerehabilitation where the patients have to do the exercises by themselves.

The last point is the sustainability of the system. We have seen that for the rehabilitation of children with cerebral palsy and weight management, most of the systems were commercial active video games. Despite the popularity in the medical community, the Wii system was discontinued in 2013 and the Kinect in 2017. In the meantime, Nintendo executives announced that they will not incorporate any active video games in their next console and games and only focus on passive video games (30). Does this mean the end of exergames? Hopefully not, there are already specific solutions that do not rely on technologies from the gaming industry. However, those solutions are more difficult to find and more expensive because of factors like the size of the market. It is therefore important to find solutions to guarantee patients a long-term sustainable use of these new tools.

Conclusion

The current gaming technology is, currently, not fully adapted to the clinics and further development and improvement are still needed. However, the existing solutions – commercial or specially developed – already offer interesting new perspectives in rehabilitation. The use of exergames increases the motivation of the patients. Therefore the patients are performing a higher number of repetitions of the exercises which has a direct positive impact on the rehabilitation. In addition to this direct aspect, the advantage of the games is that they also stimulate different cognitive functions and distract the patient which allows for other types of benefits during revalidation. Although the aspects are not fully understood and therefore the benefits of these are not yet fully implemented in rehabilitation these are very interesting perspectives for various pathologies.

Conflict of interest

No potential competing interest was reported by the author.

REFERENCES:

1. World Health Organization. World Health Organization (WHO) and World Bank World Report on Disability. 2011.
2. Demers M, Martinie O, Winstein C, Robert MT. Active Video Games and Low-Cost Virtual Reality: An Ideal Therapeutic Modality for Children With Physical Disabilities During a Global Pandemic. *Front Neurol*. 2020;11:601898.
3. Charvet LE, Yang J, Shaw MT, Sherman K, Haider L, Xu J, et al. Cognitive function in multiple sclerosis improves with telerehabilitation: Results from a randomized controlled trial. *PLoS One*. 2017;12(5):e0177177.
4. Reedman SE, Boyd RN, Ziviani J, Elliott C, Ware RS, Sakzewski L. Participation predictors for leisure-time physical activity intervention in children with cerebral palsy. *Dev Med Child Neurol*. 2021 [in Press]
5. Ramírez-Granizo IA, Ubago-Jiménez JL, González-Valero G, Puertas-Molero P, San Román-Mata S. The Effect of Physical Activity and the Use of Active Video Games: Exergames in Children and Adolescents: A Systematic Review. *IJERPH*. 2020;17(12):4243.
6. Bonnechère B, Omelina L, Jansen B, Van Sint Jan S. Balance improvement after physical therapy training using specially developed serious games for cerebral palsy children: preliminary results. *Disabil Rehabil*. 2017;39(4):403–6.
7. Bonnechère B. *Serious Games in Physical Rehabilitation: From Theory to Practice*. Springer International Publishing; 2018
8. Bonnechère B, Jansen B, Haack I, Omelina L, Feipel V, Van Sint Jan S, et al. Automated functional upper limb evaluation of patients with Friedreich ataxia using serious games rehabilitation exercises. *J Neuroeng Rehabil*. 2018;15(1):87.
9. Bonnechère B, Sholukha V, Omelina L, Van Sint Jan S, Jansen B. 3D Analysis of Upper Limbs Motion during Rehabilitation Exercises Using the Kinect™ Sensor: Development, Laboratory Validation and Clinical Application. *Sensors*. 2018;18(7):2216.
10. Bonnechère B, Jansen B, Omelina L, Van Sint Jan S. The use of commercial video games in rehabilitation: a systematic review. *Int J Rehabil Res*. 2016;39(4):277–90.
11. Langhorne P, Bernhardt J, Kwakkel G. Stroke rehabilitation. *The Lancet*. 2011;377(9778):1693–702.
12. Chen Y, Fanchiang HD, Howard A. Effectiveness of Virtual Reality in Children With Cerebral Palsy: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. *Phys Ther*. 2018;98(1):63–77.
13. Taylor MJD, McCormick D, Shawis T, Impson R, Griffin M. Activity-promoting gaming systems in exercise and rehabilitation. *JRRD*. 2011;48(10):1171.
14. Comeras-Chueca C, Villalba-Heredia L, Pérez-Llera M, Lozano-Berges G, Marín-Puyalto J, Vicente-Rodríguez G, et al. Assessment of Active Video Games' Energy Expenditure in Children with Overweight and Obesity and Differences by Gender. *Int J Environ Res Public Health*. 2020;17(18).
15. O'Donovan C, Roche EF, Hussey J. The energy cost of playing active video games in children with obesity and children of a healthy weight. *Pediatr Obes*. 2014;9(4):310–7.
16. Johnston JD, Massey AP, Marker-Hoffman RL. Using an alternate reality game to increase physical activity and decrease obesity risk of college students. *J Diabetes Sci Technol*. 2012;6(4):828–38.
17. Froome HM, Townson C, Rhodes S, Franco-Arellano B, LeSage A, Savaglio R, et al. The Effectiveness of the Foodbot Factory Mobile Serious Game on Increasing Nutrition Knowledge in Children. *Nutrients*. 2020;12(11):3413.
18. Maskey M, Lowry J, Rodgers J, McConachie H, Parr JR. Reducing Specific Phobia/Fear in Young People with Autism Spectrum Disorders (ASDs) through a Virtual Reality Environment Intervention. van der Feltz-Cornelis C, editor. *PLoS ONE*. 2014;9(7):e100374.
19. Terlouw G, van 't Veer JT, Prins JT, Kuipers DA, Pierie J-PEN. Design of a Digital Comic Creator (It's Me) to Facilitate Social Skills Training for Children With Autism Spectrum Disorder: Design Research Approach. *JMIR Ment Health*. 2020;7(7):e17260.
20. Tang JSY, Falkmer M, Chen NTM, Bølte S, Girdler S. Designing a Serious Game for Youth with ASD: Perspectives from End-Users and Professionals. *J Autism Dev Disord*. 2019;49(3):978–95.
21. Millar L, McConnachie A, Minnis H, Wilson P, Thompson L, Anzulewicz A, et al. Phase 3 diagnostic evaluation of a smart tablet serious game to identify autism in 760 children 3-5 years old in Sweden and the United Kingdom. *BMJ Open*. 2019;9(7):e026226.
22. Rantala A, Pikkariainen M, Miettunen J, He H-G, Pölkki T. The effectiveness of web-based mobile health interventions in paediatric outpatient surgery: A systematic review and meta-analysis of randomized controlled trials. *J Adv Nurs*. 2020;76(8):1949–1960
23. Yap KY-L, Koh DWH, Lee VSJ, Wong LL. Use of virtual reality in the supportive care management of paediatric patients with cancer. *Lancet Child Adolesc Health*. 2020;4(12):899–908.
24. Gates M, Hartling L, Shulhan-Kilroy J, MacGregor T, Guitard S, Wingert A, et al. Digital Technology Distraction for Acute Pain in Children: A Meta-analysis. *Pediatrics*. 2020;145(2):e20191139
25. Faber AW, Patterson DR, Bremer M. Repeated use of immersive virtual reality therapy to control pain during wound dressing changes in pediatric and adult burn patients. *J Burn Care Res*. 2013;34(5):563–8.
26. Brown SJ, Lieberman DA, Germeny BA, Fan YC, Wilson DM, Pasta DJ. Educational video game for juvenile diabetes: results of a controlled trial. *Med Inform (Lond)*. 1997;22(1):77–89.
27. Kato PM, Cole SW, Bradlyn AS, Pollock BH. A video game improves behavioral outcomes in adolescents and young adults with cancer: a randomized trial. *Pediatrics*. 2008;122(2):e305–317.
28. Joëlsson M, Lundqvist S, Larsson MEH. Tailored physical activity on prescription with follow-ups improved motivation and physical activity levels. A qualitative study of a 5-year Swedish primary care intervention. *Scand J Prim Health Care*. 2020;38(4):399–410.
29. Levac D, Rivard L, Missiuna C. Defining the active ingredients of interactive computer play interventions for children with neuromotor impairments: a scoping review. *Res Dev Disabil*. 2012;33(1):214–23.
30. Bonnechère B, Omelina L, Kostkova K, Van Sint Jan S, Jansen B. The end of active video games and the consequences for rehabilitation. *Physiother Res Int*. 2018 Oct;23(4):e1752.