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Recommendations for the Optimal Design of Exergame Interventions for Persons with Disabilities: Challenges, Best Practices, and Future Research

Josef Wiemeyer, Dr rer medic,[1] Judith Deutsch, PT, PhD, FAPTA,[2] Laurie A. Malone, PhD,[3] Jennifer L. Rowland, PT, PhD,[4] Maria C. Swartz, PhD,[5] Jianjing Xiong, MD,[6] and Fang Fang Zhang, MD, PhD[6]

Abstract

A group discussion of individuals with expertise working in the field of exergaming and rehabilitation focused on the issue of designing exergames for persons with disabilities as well as appropriate interventions using exergames. The purpose of these discussions was to develop recommendations for the design, evaluation, and application of exergames in therapy serving as potential guidelines for researchers, developers, and therapists. The following key issues were addressed: (1) Challenges in exergame design for persons with disabilities, (2) adaptation of exergames for persons with disabilities, (3) exergame interventions, and (4) future research directions. It is the hope of the group that the results of these recommendations will help improve the quality of exergame design and interventions and thereby increase opportunities for persons with disabilities to engage sustainably in exergaming.

Introduction

Persons with disabilities make up about 15.6 percent of the world population[1] and constitute the largest minority group.[2] According to the World Health Organization, disability is an ''umbrella term for impairments, activity limitations and participation restrictions. It denotes the negative aspects of the interaction between an individual (with a health condition) and that individual's contextual factors (environmental and personal factors).''[3] In 2008 the United Nations held a convention to ''promote, protect and ensure the full and equal enjoyment of all human rights and fundamental freedoms by all persons with disabilities, and to promote respect for their inherent dignity'' (Article 1).[4]

Rehabilitation aims to improve the health status of persons with disabilities and thereby enhance activity and participation. Exergames are a potential rehabilitation tool for increasing physical activity and improving health status. Exergames are a combination of exercise or exertion and (digital) games. In particular, we refer to digital games that require actions of large body parts (like trunk or upper or lower extremity, as acompared with finger or hand movements in non-exergames) or the whole body to control gameplay. Depending on the game design, exergames may be used to improve cardiorespiratory fitness or enhance sensorimotor control. Evidence for efficacy of exergame interventions for persons with disabilities is still limited but promising. Reviews indicate that exergames have positive effects both on motivation for active participation in rehabilitation and on impaired functions. However, many studies have shortcomings, including small sample size, lack of control group, and poor control of experimental conditions.[5] Furthermore, there is still a long way to go to systematically exploit the potentials of exergames for persons with disabilities.

At the symposium ''Games for Increasing Physical Activity: Mechanisms for Change,'' which was held in Houston, TX, in May 2014, a working group of invited individuals with expertise in the field of (exer)games in prevention and therapy (i.e., the authors of this article) discussed issues surrounding optimal exergame design and intervention for persons with disabilities. The purpose of these discussions was to develop recommendations for the design, evaluation,

[1]Institute of Sport Science, Technische Universität Darmstadt, Darmstadt, Germany.
[2]Rutgers Behavioral Health Sciences University, Newark, New Jersey.
[3]UAB/Lakeshore Research Collaborative, Birmingham, Alabama.
[4]University of Texas Medical Branch, Galveston, Texas.
[5]The University of Texas MD Anderson Cancer Center, Houston, Texas.
[6]Tufts University, Boston, Massachusetts.
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and application of exergames in therapy. We hope that that this article will serve as potential guidelines for researchers, developers, and therapists. We addressed two specific aspects of exergames: (1) Design and (2) application (including evaluation). In this article, we summarize and extend the results from our working group discussion.

Challenges in Exergame Design for Persons with Disabilities

Design of exergames for use by persons with disabilities requires consideration of barriers to accessibility such as operating the game interface, perceiving game events, and production of movements required for gameplay as well as specific benefits and risks. It is essential to involve the end user—the person with disabilities, the family members, and clinicians who may interact with the person and the games.[6] Therefore, developing optimal exergame designs and targeted interventions for persons with disabilities requires a multifaceted approach.

The design of exergames encompasses all components of a game (e.g., game mechanics, game dynamics, game esthetics, game narratives, game content, game interfaces, game characters, etc.).[7,8] The most important feature of an exergame applied to persons with disabilities is an appropriate fit of game design and the characteristics of the target group.[6,9]

For persons with disabilities it is important to determine their impairments and abilities. We recommend that during the design and development phase of an exergame, researchers and game developers consider using the International Classification of Functioning, Disabilities and Health (ICF) schema proposed by the World Health Organization[3,10] to assess the functioning level of their target population. This classification scheme comprises three levels—with the first level subdivided into two sublevels (Table 1). The severity of the impairments can be classified using a five-stage scoring system (no, mild, moderate, severe, and complete). This means that either exergames can focus on a single aspect of the ICF, or they may adjust difficulty level by considering the ICF. Beyond the criteria embraced by the ICF scheme, age, gender, and individual needs, target population preferences, and therapeutic goals are additional aspects that need to be considered during the design and development stage of an exergame.

An overarching theme of the group discussion was the importance of a holistic approach to exergame design and development. Specifically, we recommend that game developers consider two major aspects. First, one must consider the target group's physiological, psychological, social, and therapeutic needs. For example, certain populations may have difficulty understanding complicated game instructions, processing visual and/or acoustic feedback information (particularly under time pressure), or operating a game controller with many small buttons. Second, beyond accomplishing the therapeutic goals, there is a need to ensure that the true game experience is not compromised. In other words, the accomplishment of the therapy or exercise goals should be seamlessly integrated into the exergame. Some existing concepts for game design[8,11,12] represent promising steps in the right direction of structured game development but need to be tailored to the specific design needs for individuals with disabilities. A specific corridor of task demands and individual skills has to be established and dynamically adapted to ensure appropriate game experience for persons with disabilities. The game experience includes fun, challenge, immersion, flow, competence, tension, curiosity, motivation, and positive emotion. This means that, on the one hand, impaired physiological function should improve, and activity limitation and participation restrictions should be reduced, and, on the other hand, a true game experience should be elicited.

It is important that game technology must be easy to use and that the game must be adaptable to the individual as described below.[6,9] Based on the best available evidence, rewards and feedback as well as social interactions should also be tailored to the specific needs of the population.

Adaptations of Exergames for Persons with Disabilities

To fit the conditions of the target group, the game design has to be dynamically adapted. These adaptations pertain to different components of game design (e.g., game mechanics, game interfaces, and gameplay). Some examples include:

- The game interface is altered (e.g., reducing complexity by limiting number of buttons required for play).
- The game interface is secured (e.g., a handrail around a balance board or placing the balance board on a wheelchair).
- The pace of the game is adapted to match the respective speed of information processing.
- The difficulty of the tasks is adapted to the current state of the individual (e.g., size of target zones, distance of targets, or resistance).[13] Two options seem feasible: Either automatic adaptation by appropriate algorithms or manual adaptation by the therapist, program provider, or caregiver. Adaptation by the patient him- or herself is potentially challenging. Self-adaptation, on

Table 1. International Classification of Functioning, Disabilities, and Health Classification Schema[3,10]

Level	*Specification*
1a. Impairment of body functions	Mental, sensory, voice/speech, cardiopulmonary, digestion, reproduction, neuromuscular, skin
1b. Impairment of body structures	Nervous system, eyes, voice/speech, cardiopulmonary, digestion, reproduction, neuromuscular, skin
2. Activity limitations and participation restrictions	Learning/knowledge application, general tasks, communication, mobility, self-care, domestic life, interpersonal interactions and relationships, major life areas (e.g., school, economy), community/social/civic life
3. Environmental factors	Technology, natural environment (e.g., climate), social support and relations, attitudes, services/systems/policies

the one hand, enhances self-determination and therefore intrinsic motivation but, on the other hand, may overload the patient, which may lead to de-motivation.

From the examples above, it becomes clear that adaptation plays a crucial role in the design of appropriate games for persons with disabilities. Adaptations of exergames can pertain to different aspects ranging from permanent (static) adaptations of hardware to transient adaptations of gaming and training properties.[14,15] Additionally, adaptations are important to establish the successful solution of the tasks in the exergame to foster both effectiveness and attractiveness of exergaming.[16]

Further principles pertain to the delivery of appropriate feedback:

- Negative feedback should be avoided. Instead, specific positive feedback should be applied.
- Schematic and generic positive feedback should be avoided. Instead, realistic, specific, and individually tailored feedback is recommended.
- Rewarding feedback, such as knowledge of results, should be presented to support intrinsic motivation (for a classification of game rewards, see Phillips et al.[17]).

Exergame Interventions for Persons with Disabilities

Evidence for positive outcomes (i.e., sensorimotor functions like upper extremity functions, activities of daily living and balance) associated with exergaming interventions has mainly focused on individuals poststroke[18] and individuals diagnosed with Parkinson's disease.[19] There are also studies that are seeking to describe the amount of effort measured by energy expenditure for persons poststroke[20] and persons with cerebral palsy[21] (see Deutsch et al.[22] in this issue for more details).

In all these application areas, only a few randomized controlled trials are available. Most studies are technical reports, case reports, or pilot or feasibility studies. Many of the intervention studies lack appropriate (e.g., behavior change) theory, multidisciplinary approach, appropriate control of conditions, appropriate control groups (traditional treatment and no-treatment), and long-term follow-ups. Therefore, it is premature to draw a conclusion about the efficacy of exergame interventions for persons with disabilities. Rather, recommendations for future interventions are discussed.

The application of exergames among persons with disabilities typically happens as an individualized intervention; consequently, it is challenging to establish large samples treated over a reasonable time frame and under comparable conditions. Exergame interventions should consider all relevant theories, ranging from generic models of behavior change (e.g., Theory of Planned Behavior, Theory of Reasoned Action, Social Cognitive Theory[23]), motivation (e.g., Self-Determination Theory, Information–Motivation–Behavioral Skills Model), exercise physiology, and game experience (e.g., dual-flow model[16]) to specific models of the respective application area (e.g., motor learning, sensorimotor processing, and task-specific training).

Other factors researchers working with exergame developers need to incorporate into their intervention plan include the setting or context of the intervention given that interventions span a large spectrum ranging from hospital to rehabilitation at home to a component of daily physical activity. Furthermore, exergames intended for physical rehabilitation in the hospital setting should be introduced presurgery to better prepare individuals for using the exergame after surgery.

When designing exergame interventions other considerations include:

- Scheduling the intervention with school, work, or rehabilitation schedule
- Ensuring safety
- Considering adaptations necessary for participation in exergaming activities
- Overcoming barriers like lack of motivation and compliance
- Integrating game activities with peers and or families.

Scientific Process for Game Design and Intervention Testing

Consistent with a user-centered approach, we recommend that game development be informed by the end user. Typically, usability and validation studies precede efficacy studies. It should be assumed that the game design will be iterative.[9] Following these studies one can design pilot and proof-of-concept studies.[24] Determining efficacy and efficiency of exergames should be delivered by performing appropriately powered randomized controlled trials using standardized quantitative measures. However, just as important is additional information obtained by qualitative data. To overcome the small sample size challenge, researchers should consider collaboration across different institutions and build collaboration with rehabilitation and community groups to ensure that an adequate sample size can be obtained. Alternatively, well-constructed serial single-subject designs may provide evidence for application to people with disabilities who have rare conditions.

An informed design process is exemplified in the approach of Rochester and co-workers. First, they reviewed the literature on use of videogames to improve sensorimotor control in persons with Parkinson's disease.[19] The results were equivocal, and this prompted their venture into designing a game for the Microsoft (Redmond, WA) Kinect™. An interdisciplinary team of clinician-scientists (human–computer interface experts) queried individuals diagnosed with Parkinson's disease and clinicians who work with them as the basis for the game designed to improve postural control. They addressed both the design requirements and the safety and feasibility of playing the game.[25]

Recommendations for Future Research

Game design as a collaborative and interdisciplinary process

In the game design process, the interdisciplinary collaboration of different disciplines is required. A particular issue of collaboration is the use of different terminologies. For example, the term ''activity'' has quite different meanings for a game designer and a physical therapist. One option for establishing a common language is to use a glossary where the relevant terms for the project are defined.

Another important issue is the fact that parallel developments may take place at different locations. On the one hand, working on similar projects at different places may contribute

to a reasonable variety of solutions. On the other hand, unnecessary redundant work may waste resources needed for other projects. Therefore, multicenter collaborations are considered a viable way to coordinate research and development of exergames dedicated to specific target groups in order to efficiently allocate human and technological resources. Idea sharing and crowd sourcing at relevant game design conferences may stimulate creative solutions to the challenge of designing exergames for people with disabilities.

Exergame database

Existing Web sites listing games for health (e.g., healthgamesresearch.org) are a reasonable first step to archiving and retrieval of exergames available for therapy. However, they offer very few arbitrary categories for retrieval like selected characteristics of the target group (e.g., age or disease) and platform. Archiving games for health would benefit considerably from a more elaborate metadata format systematically embracing all relevant features of exergames. Considering the variety of exergames that have been and are still to be developed, adapted, and applied, including off-the-shelf as well as self-developed exergames, a database makes sense where all exergames are documented (Stefan Goebel[26] provided a presentation on this topic at this meeting). Respective metadata on exergames bearing relevant information for therapists and program providers should include the following aspects (but not limited to):

- Game platform
- Target group(s) (e.g., age, gender, disabilities [type, grade])
- Health considerations (e.g., cancer, stroke, diabetes, obesity)
- Application or intervention areas (e.g., cardiorespiratory, strength, coordination, nutrition, mobility, fitness)
- Load characteristics [e.g., intensity level(s), duration, volume, complexity]
- Indications and contraindications (e.g., seizure or cardiovascular complications)
- Settings (e.g., hospital, school, home; individual training, group intervention)
- Outcome measures (e.g., clinical scales, questionnaires, performance measures)
- Evidence (e.g., randomized controlled trials, pilot studies, feasibility studies).

Conclusions

The workgroup discussion identified multiple considerations to ensure optimal design of exergames and interventions for persons with disabilities.

The following aspects were considered as key issues that need to be addressed in future research:

- Appropriate fit of game design and the specific characteristics of the target audience (user-centered design)
- Interventions using exergames that were either customized or specifically developed for persons with disabilities
- (Dynamic) adaptation of exergame design features (e.g., interactive elements, rules, and narratives) to ensure both efficacy and attractiveness
- Sound scientific substantiation of both exergame and treatment, along with appropriately powered research designs, including mixed methods ranging from standardized quantitative to qualitative data acquisition and representative samples of the respective target group
- Collaboration (interdisciplinary teams as well as multicenter projects)
- Establishing an exergame database containing all relevant information (metadata) required for appropriate selection and application of exergames.

It is the hope of this group that the quality of future exergame design and intervention development will improve considerably if these key issues are addressed.

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Address correspondence to:
Josef Wiemeyer, Dr. rer medic
Institute of Sport Science
Technische Universität Darmstadt
Magdalenenstrasse 27
64289 Darmstadt, Germany

E-mail: wiemeyer@sport.tu-darmstadt.de