The use of *gamification* within motion-based interventions for children with cerebral palsy

- a systematic review -

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Structure of this Bachelorthesis

The thesis starts with a cover page, followed by an abstract. The abstract is written twice in English and in Dutch. I decided to write the entire thesis in English and appreciate the opportunity to get more confident in this foreign language. I´m a native German who´s studies abroad in the Netherlands, which opens up new horizons for me. The Netherlands are very advanced in the use of technology, especially at the University of Twente. This reinforces my decision to explore the topic of this thesis. After the abstract, a section of acknowledgement and a table of content comes up.

The introduction (1) of this thesis outlines the problem of the disease cerebral palsy by giving a description of its etiology, it´s manifestation and pathology and current treatment methods. Besides, the introduction gives a theoretical overview of the research questions, which belong to gamification as possible treatment method.

The next part is the method section (2). At this point the research methods and methodological process of the systematic literature search are highlighted. This section ends with a list of suited articles.

Based on selected articles, the results emerge (3). In this section all findings from the assessment and evaluation of the articles are shown.

This is followed by a discussion section (4) concerning implication for future research in the field of cerebral palsy treatment. Current interventions will be compared and their feasibility as game-interventions will be examined. This leads to a brief conclusion about this topic based on the articles found in this review.

At the end a list of references (5) will be given.

Abstract

Title: The use of *gamification* within motion-based interventions for children with cerebral palsy

Background: Cerebral palsy is an umbrella-term used to describe a group of non-progressive disorders affecting predominantly voluntary movement and coordination. The functional impairment is a result of a lifelong damage to the brain. Current rehabilitation strategies for children with cerebral palsy focus on physical therapy of those body parts that are affected by functional impairments. Even though physical therapy methods are valued as effective, patients often have a lack of adherence to this treatment which could result in an unexploited potential of the exercise program. Gamification, which focuses on the implementation of game-methods, can facilitate the compliance by enhancing the patient's motivation. Motion games as a therapeutic modality are novelties, whose effectiveness is promising based on current research.

Objective: The general purpose of this study is to outline the feasibility of gamification as a method in physical rehabilitation programs within a population of children with cerebral palsy. In order to attain an overview of the current level of evidence a systematic literature study for existing intervention was conducted. A collection of 13 studies by a database (EndNote library), which has already been obtained in 2013, met the inclusion criteria of this review. The studies regarding game-based treatment are directed at the main functional conditions, such as promoting physical activity, motor control and balance. The intention is to provide systematic assessment of the prospects and opportunities of game-based therapy for children with cerebral palsy and to create a path for further studies in this research area.

Results: The amount of game-based interventions was small amongst studies about physical therapy for cerebral palsy. Most of the selected articles were pilot studies or case studies, using only a small sample size. There was mostly an absence of well-designed and controlled research. Based on the findings of this review the game-based therapy is not more effective than conventional physical therapy. However nine studies concluded that games promote the motivation to practice and lead to an increased physical activity in both therapeutic and home-based therapy settings. This indicates that the use of motion games in rehabilitation for children with cerebral palsy could potentially offer a unique new approach to promoting exercise and physical training.

Conclusion: The outcomes from the reviewed interventions deliver preliminary support for the use of game-based physical treatment for children with cerebral palsy. However the feasibility of gamification as an effective treatment method for cerebral palsy has to be taken with caution. The generalizability of the study is restricted by a number of methodological limitations. Specific effects on functional physical impairments need to be explored through more reliable and adequate research design. In the future more convincing research will be needed, which primarily concentrates on children´s requirements while optimizing an individualized physical training.

Samenvatting

Titel: Het gebruik van *gamification* binnen beweging gebaseerde interventies voor kinderen met cerebrale parese

Achtergrond: Cerebrale parese is een algemene begrip voor een groep van niet-progressieve aandoeningen die voornamelijk vrijwillige beweging en coördinatie beïnvloeden. De functionele beperkingen zijn het gevolg van een permanente hersenschade. Huidige rehabilitatie strategieën voor kinderen met cerebrale parese richten zich vooral op fysiotherapie betreffende de lichaamsdelen met functionele beperkingen. Hoewel fysiotherapeutische methoden als effectieve worden gezien, missen patiënten vaak de nodige enthousiasme en ijver wat een onbenut potentieel van het oefenprogramma tot gevolg heeft. Gamification, dat zich richt op het gebruik van het game-methoden, kan de participatie bevorderen door de motivatie van de patiënten te versterken. Bewegings-gebaseerde games als therapeutische modaliteit is nieuw en de resultaten van tegenwoordige onderzoeken zijn veelbelovend.

Doel: Het algemene doel van deze thesis is om de haalbaarheid van gamification als een methode in fysieke revalidatie programma's binnen een populatie van kinderen met cerebrale parese te schetsen. Om een overzicht van het huidige niveau van bewijs te bereiken, wordt een systematische literatuurstudie van bestaande interventies uitgevoerd. Een verzameling van 13 studies uit een eerder verzamelde database (EndNote bestand) voldeed aan de inclusiecriteria van deze literatuurstudie. De studies met betrekking tot game-gebaseerde behandeling worden gericht op de belangrijkste functionele aandoeningen, zoals het bevorderen van lichaamsbeweging, motorische controle en balans. De doelstelling is een systematische beoordeling van de vooruitzichten en de mogelijkheden van game-gebaseerde therapieën te bieden en een pad voor verdere studies op dit onderzoeksgebied te leggen.

Resultaten: Het aantal van game-gebaseerde interventies onder de fysiotherapie studies is klein. De meeste van de geselecteerde artikelen waren pilotstudies of case studies met slechts kleine steekproeven. Er was vooral een gebrek aan goed ontworpen en gecontroleerd onderzoek. Op basis van de bevindingen is de game-gebaseerde therapie niet effectiever dan conventionele fysiotherapie. Desondanks concludeerden negen studies dat games de motivatie om te oefenen bevorderen en tot een verhoogde lichamelijke activiteit in zowel therapeutische en huis-gebaseerde therapie-instellingen leiden. Dit wijst op een veelbelovend potentieel in het gebruik van beweging games in rehabilitatie voor kinderen met cerebrale parese en het lijkt het algemene fysieke training te bevorderen.

Conclusie: De uitkomsten leveren voorlopige steun voor het gebruik van de game-gebaseerde fysieke behandeling voor kinderen met cerebrale parese. De haalbaarheid van gamification als effectieve behandelingsmethode moet echter met voorzichtigheid worden beschouwd, omdat de generaliseerbaarheid van de interventies wordt bemoeilijkt door methodologische beperkingen. Specifieke effecten op functionele lichamelijke beperkingen moeten verder worden onderzocht met een meer betrouwbare en adequate onderzoeksopzet. Toekomstig onderzoek is nodig, dat in eerste plaats is geconcentreerd op de behoeftes van de kinderen. Dit kan door een optimalisatie van de geïndividualiseerde fysieke training worden bereikt.

Acknowledgement

First and foremost, I would like to thank my supervisors' dr. Elian de Kleine and dr. Saskia M. Kelders for giving me the opportunity to write this thesis. I am grateful for their guidance and support throughout the work with this thesis. I appreciate your interest in this work and I always felt your help when needed.

Furthermore I would like to acknowledge the cooperation with my fellow student Isabel Barton, who gave me practical support when needed and was always willing to answer my questions.

Last but not least I would like to express my sincere gratitude to all my friends and acquaintances who made linguistic improvements and checked the spelling of this thesis. They were constantly available during my writing process and spent the time to assist me in my work.

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Introduction

Imagine you want to reach for a bottle of water or you want to stand up, but your body doesn't obey your command. Imagine you can't move your body voluntarily and your body even moves without your willpower. Imagine every motion is accompanied by pain.

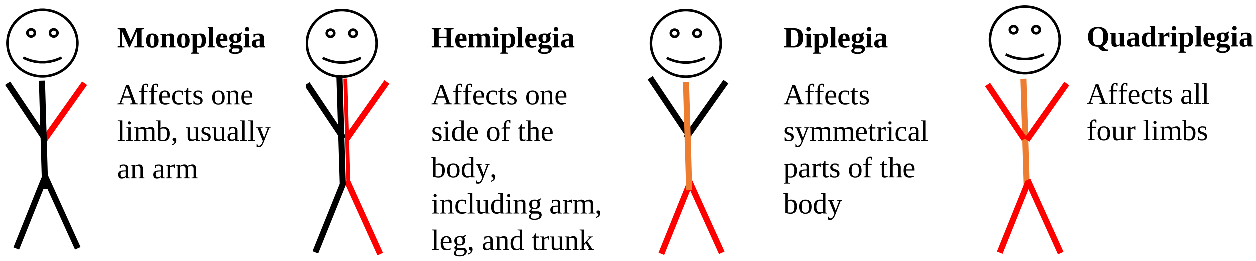
Children, who have the chronic disability ´cerebral palsy` suffer from these exhaustive experiences. In the Netherlands between 1,5 to 2,5 children per 1000 live births face this physical and psychological distress (Wichers, Van der Schouw, Moons, Stam & Van Nieuwenhuizen, 1977-1988). Based on the European prevalence rates that ranges from 0.8 to 3.0 per 1,000 live births, cerebral palsy is considered one of the most common motor deficiency in early childhood (Cans, 2000; Odding, Roebroeck & Stam, 2006).

Cerebral palsy is an umbrella-term for a variety of disorders affecting body movement, balance and posture. Although one might assume that the disorder emerges due to a damage occurring to the nerves or muscles, it is not the case. Instead, cerebral palsy is the result of a permanent and non-progressive abnormality in the immature brain (Rosenbaum, Paneth, Leviton, Goldstein, Bax, Damiano, Dan & Jacobsson, 2007). This is usually caused by a diminished blood supply and lack of oxygen, but definite clarity about the roots does not exist (Wichers et al., 1977-1988; Cans, 2000). The impairments associated with the disorder may change with age, although the brain-damage is of a static nature and non-progressive (Piek, 2006). The brain-damage affects the child´s ability to control and coordinate its muscle tone and motor activity (Rosenbaum et al., 2007). Some children, whose brain damage doesn't impair their intellectual ability, are completely aware of the uncontrollability of their body (NCB: Scope, 2012). Depending on the extent and localization of the brain injury concomitant disorders can occur. Besides kinetic disabilities, children may face disturbances of sensation, deficiencies in perception and reduction of cognitive capabilities. They are also often handicapped in their ability to communicate as well. On top of that, their motor disorders can be accompanied by epilepsy and secondary musculoskeletal problems (Rosenbaum et al., 2007). Unfortunately, this illustrates that the problems of cerebral palsy patients are more extensive than motor impairments alone.

Because of the physical impairments and the great number of additional effects the children need personal care in a particular way. Movements can be painful and agonizing without special assistance (NCB: Scope, 2012). The need of extraordinary care emphasizes that the consequences of cerebral palsy are more far-reaching than the effects of the disease itself. In this regard, it also gives a great burden to the caregivers of patients with cerebral palsy. They are confronted with structural constraints and experience emotional distress (Uldall, 2012). Correspondingly, caregivers often describe their life situations as “a daily battle” (Fernández-Alcántara, García-Caro, Laynez-Rubio, Pérez-Marfil, Martí-García, Benítez-Feliponi & Cruz-Quintana, 2015). Besides, enormous costs for the whole society arise due to the disease. According to Honeycutt, Grosse, Dunlap (2003) the lifetime-costs for cerebral palsy patients amount to 11,470 million dollars. These are partly ascribed to the incurability of the disease up to this date. Based on the health conditions of children with cerebral palsy and the undesirable side-effects, attention is paid to current treatment and therapy approaches.

In practice, it is difficult to find a single, unified solution fitting to all impairments because infantile cerebral palsy is influenced by a variety of factors. The extent of motor and cognitive limitations as well as occurring concomitant disorders varies enormously. Likewise, the forms of cerebral palsy differ in manifestations. This makes each case unique. The loss of motor control relates to different parts of the body, depending on the topographical location of the brain-damage (Cans, 2000). According to this different muscle control, impairments are related to different limbs, which is illustrated in *figure 1*. If the location of the primary motor disability only affects one limb, it is labeled as monoplegia. Hemiplegia means the motor damage is centered on one side of the body. Diplegia usually indicates that the lower body is primarily affected, but upper limbs could also be impaired. At last, all four limbs are paralyzed or weakened by quadriplegia.

Figure 1: distribution of limb weakness



The distinct types of motor impairments are again classified into three main categorizations (Cans, 2000; Rosenbaum et al., 2007). The majority of cerebral palsy cases is called *spastic* type. 70% to 85% of the children belong to this group, which is characterized by an increased muscle tone (Jones, Morgan, Shelton & Thorogood, 2007). Their muscles are stiff and their movements are awkward. The second category describes *dyskinetic* cerebral palsy. Children within this category suffer from uncontrollable, slow or rapid movements. They often have trouble with sitting, walking and talking. The last group is called *ataxic* cerebral palsy, which means that children primarily show balance and coordination problems. It is especially difficult for them to carry out movements that need a lot of control, like writing or reaching (Cans, 2000; Rosenbaum et al., 2007).

As a result, it is often stated that people diagnosed with cerebral palsy are a very heterogeneous group (Palisano, Rosenbaum, Barlett, Livingston, 2008). Developers of intervention-programs are confronted with the challenge to integrate all disparate forms of cerebral palsy in one therapy and to meet the special needs of every individual child.

Current treatments focus on the development of as many motor skills as possible or on a compensation for the lack of them. Optimal treatment requires a focus on the whole development and not on single symptoms. The best known forms of therapies for people living with cerebral palsy are neurodevelopmental treatments, conductive education, surgery treatment, medication, physical and occupational therapy (Freeman, 2005; Novak, Mcintyre, Morgan, Campbell, Stumbles, Wilson & Goldsmith, 2013). Unfortunately, most of these treatments lack effectiveness. With neurodevelopmental treatments children gain control over sensorimotor components of muscle tone, movement patterns and perception. Research on such techniques does not demonstrate robust evidence of effectiveness (Freeman, 2005; Novak et al., 2013). There are a few significant functional gains, but in sum higher motor functioning does not improve. In the course of conductive education children are taught strategies to consciously perform actions. Children without cerebral palsy learn these strategies through normal life experiences. Conductive techniques belong to interventions within clinical care that have low or inconclusive evidence supporting their effectiveness (Freeman, 2005; Novak et al., 2013).

In contrast, surgery treatment seems effective in treating cerebral palsy. For example, it eliminates spasticity by cutting dorsal rootlets from spinal cord segments. Nevertheless, because of its irreversibility the treatment should only be used as a last option and in extreme cases (Freeman, 2005). Pharmacological agents have also shown benefits in reducing muscle spasticity. Medication is aiming at muscle-relaxation by affecting the central nervous system. However, the numerous side-effects are not well tolerated by children (Freeman, 2005).

Notwithstanding that all mentioned treatments do not contribute to improvements or have negative side-effects, physical and occupational therapies have shown promising results. It is considered that greater muscle strength is a contributor to improve balance and coordination in children with cerebral palsy. Physical therapy mainly specializes in gross motor functions, such as walking and running, whereas the occupational therapy focuses on fine motor functions and daily activities like dressing and toileting. The therapies are proven to be effective interventions for cerebral palsy, especially when they are goal-directed, home-based and context-focused (Freeman, 2005; Novak et al., 2013).

However, McLean, Burton, Bradley and Littlewood (2010) have shown in their review that the patient´s adherence to physical therapy is problematic. Enrolled in a physical therapy program patients are required to maintain the procedures routinely. The therapy is often perceived as monotonous and mundane. Besides, the behaviors that the patients are required to undergo during the procedure can be perceived as painful or aversive. Consequently, this affects the motivation to follow the recommended training exercise. If such poor compliance on a patient-related level is given, the forecasted profit of the exercise will be unexploited.

Games provide prospects to surmount the barriers that prevent patients from taking full advantage of the possibilities that the health care system has to offer. According to a review of Kato (2010) patients cooperate with the course of physical therapy, if the procedures are integrated into a part of an entertaining game. The main mechanism behind a game-based approach is the ability of games to increase motivation. Games with appropriate features divert attention away from aversive side effects. In this way, the key factor of games in improving therapeutic effects is their creation of engaging distraction (Kato, 2010). Furthermore, the practice of gaming seems to present an excellent opportunity to reinforce children the correct way to conduct their physical therapy regime because games may be able to meet the different needs of the individual child (Göbel, Hardy, Wendel, Mehm & Steinmetz, 2010). It is possible to include an adaptive component in the game-programs, like the measuring of vital parameters in order to adjust the difficulty of game-play to the user. If the tailored game fits the user´s needs, the attractiveness of gaming will be enhanced. This gives great benefits to the therapy´s effectiveness of cerebral palsy and provides support for the development of a universal therapy program (Göbel et al., 2010).

The process of using game elements to increase the motivation of people in non-game context, is called g*amification*. More precisely the term symbolizes the integration of game mechanisms with health theories and behavioral insights (Deterding, Miguel, Nacke, O'Hara, Dixon, 2011). In order to achieve a successful game-play game elements has to be taken into account to achieve motivation (Deterding, 2012). Bryanton, Bosse, Brien, Mclean, McCormick and Sveistrup (2006) confirmed this by showing that children express more fun during game exercises than during conventional exercises. They revealed that children with cerebral palsy are motivated to play action-oriented and fast-paced games.

In connection with this, Lepper and Malone (1987) revealed that four major factors or elements are intrinsically motivating the game activity. The first factor is labeled *challenge*. It covers goal statements and performance feedback that have to be clear, constructive and encouraging in order to increase the player's confidence. Secondly, stimulating *curiosity*, an element of surprise, is important for motivation. The third element is *control*. This has to be tied to the player's belief in his or her capability of succeeding. The last factor is *fantasy*. Hypothetical, the most motivating fantasies are obtained by role playing.

Games can be specifically designed for a significant real-life purpose as a means to improve their health outcomes. Those games are called "serious games". Their main goal is to achieve education, training, rehabilitation, and exercise through entertainment (Mader, Natkin & Levieux, 2012). Serious games need to be differentiated from the term *gamification* which describes the application of game elements offering "gameful" experience and does not aim at creating a game (Deterding et al., 2011). Already in the 1980s games were used as means of health-care (Kato, 2010). Nowadays, new and inexpensive technologies provide innovative opportunities of applying games to health promotion. The mainstream attention is directed towards new control technologies, such as Nintendo Wii and Kinect. Video-games which exclusively promote physical activity are "exergames" (Betker, Szturm, Moussavi & Nett, 2006). Several studies have implemented this method to design interventions for physical therapy and the research in this area is still growing. A therapeutic success of exergames has already been reported for arm injuries, Erb´s palsy, traumatic brain injuries and obesity (Kato, 2010). Although a potential of games to positively influence physical impairments is demonstrated, supportive evidence for their application in rehabilitation therapies for cerebral palsy is still poor (Brütsch et al., 2011). Remarkably, only a few studies are dealing with this research subject and only a small number evaluated outcomes are documented (Kato, 2010). It´s interesting to see whether the results of these studies provide a first step for a future integration of gamification in physical therapies for children with cerebral palsy. Therefore, this review aimed at an investigation of how gamification can be integrated into a part of a treatment for children with cerebral palsy. The study´s purpose was not placed on giving preference to one kind of treatment, but to highlight and identify the characteristics of game-interventions as a possibility for further treatment procedures. To deliver recommendations for future research, existing game-based treatment-programs of cerebral palsy will be considered in detail and available information about the possibilities of the application as a therapeutic intervention will be explored. In order to get a detailed picture of the findings of the existing literature a comprehensive literature search will be done according to the guidelines of the PRISMA-P protocol (Moher, Shamseer, Clarke, Ghersi, Liberati, Petticrew & Stewart, 2015).

The following research questions and sub-questions were formulated leading to an accurate insight into the use of gamification and serious games within interventions for children with cerebral palsy:

1. What are the characteristics of present interventions using gamification for children with cerebral palsy?
    1.1. How is the intervention set up?
    1.2. What is the target group of the intervention?
    1.3. What physical skills and behaviors of patients with cerebral palsy are the intervention aiming to alter with game methods?
2. What are the characteristics of the games used in physical interventions that are directed at children with cerebral palsy?
    2.1. Which platform and device are used to implement the game-method?
    2.2. What are the game design elements used to execute the game?
3. Which limitations arise in the study- and intervention design of game-based therapy approaches?
4. What is the effectiveness of gamification in cerebral palsy interventions for children?

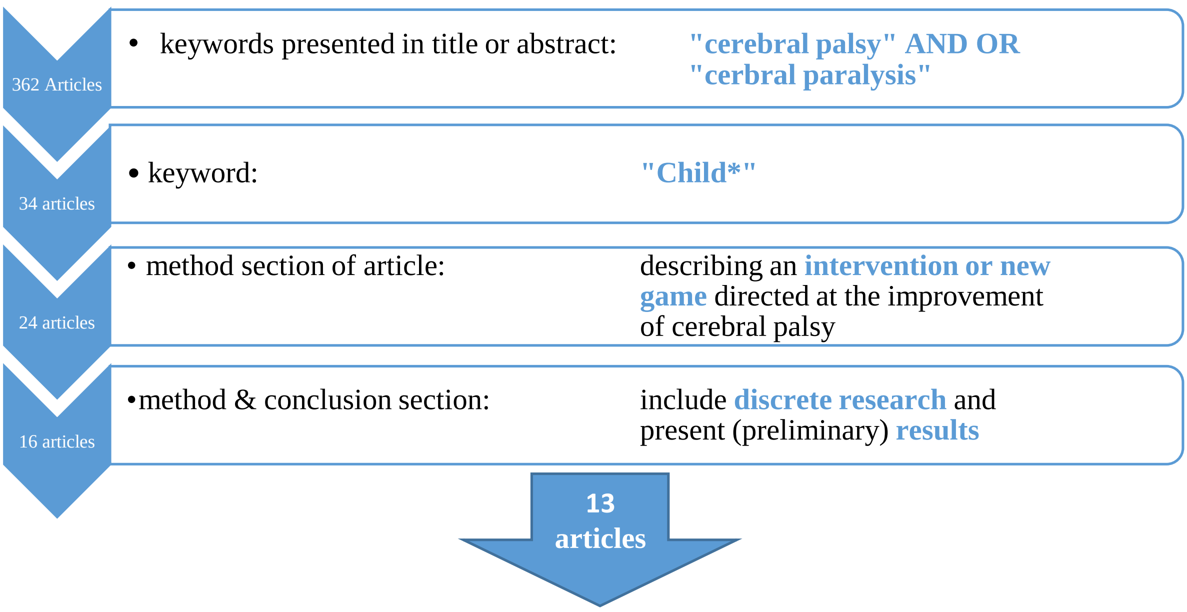
Methods of literature review

Systematic literature search

This thesis used the method of a comprehensive literature search to find answers to the research questions that are set. The search constructs were formed in accordance with the four-phase flow-diagram established by PRISMA. The extraction process of this flow-diagram is illustrated in *Figure 2*. To find suitable articles the search was being performed on an already existing data base consisting of 362 articles. These articles were selected as a part of the University of Twente´s bachelor degree program a year ago. This bigger research was conducted to gain insight into the integration of game and game-elements into health related interventions- and therapeutic programs. Therefore database consisted only of studies that use games in the field of health care. All articles obtained in the prior literature search were captured in reference system EndNote® of Thomson Reuters, New York, USA. In this paper the search took place at a more specific issue under the framework „the use of games and gamification for the treatment of cerebral palsy“. Due to that fact the data-base was reduced to the articles that were relevant to this topic.

In order to search efficiently and effectively ´Boolean operators` and ´Trunciation` were taken into account. These allowed to combine search terms and to broaden the search. By means of this, it was ensured that all articles holding relevant information on the topic were retrieved from the data-base. The constructs and the respective central terms belonging to the constructs are illustrated in *Figure 1*.

Figure 1: Search strategy



In this paper the already given 362 articles from the database were checked for their significance for the research questions. For the purpose of the study relevant eligibility criteria have been determined in advance. The generated criteria cover „inclusion criteria in the screening process“, which were as followed:

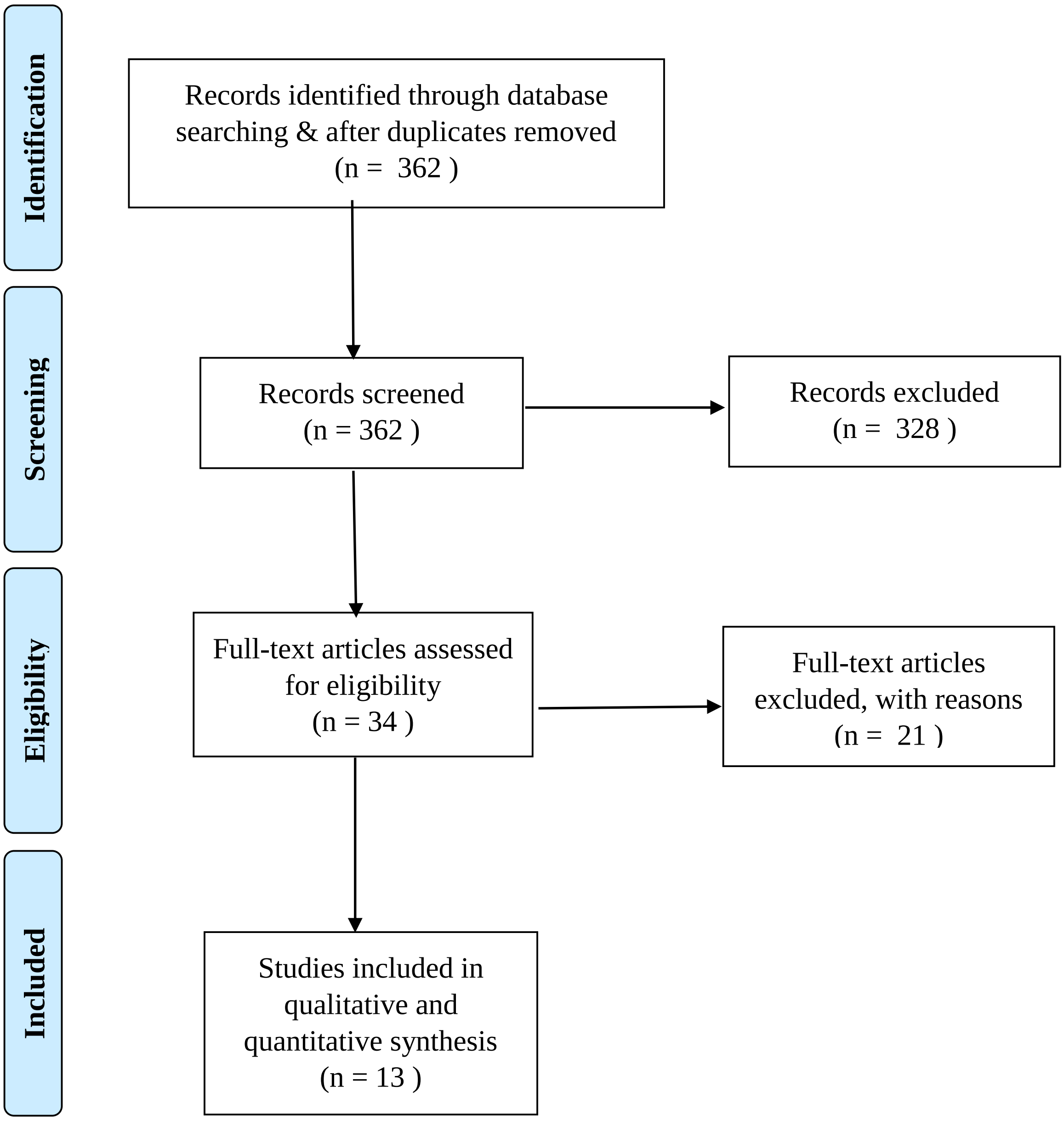
1. The article includes an intervention or a therapy approach
2. The intervention design is a pilot study, a case study or a feasibility study or include a pre- and post-test trial
3. The intervention is aimed at patients with cerebral palsy,
4. The patients are not older than 17 years,
5. The intervention focusses on rehabilitation or intends to promote physical activity, motor performance and balance
6. The intervention has to contain a game or at least game elements
7. The study has to be retrievable by digital means, and
8. The study has to be available either in English, Dutch or German.

If an article does not meet at least one of the mentioned inclusion criteria, it will be excluded from the search.

The screening process

The present review laid a special focus on interventions that includes games and serious games for the health promotion of children with cerebral palsy. Regarding to this thematic emphasis the following inclusion and exclusion criteria were stipulated supporting the screening process. The literature search has been carried out on April 7th, 2015 and led to critical summary of 13 carefully selected authoritative studies. An overview of the literature search is given by a flow-diagram (see figure 2).

Figure 2: Flow-diagram of literature search



During the first screening wave the initial identified records were screened, while looking at the headings and abstracts. At this step interventions were filtered out that addressed patients with cerebral palsy. This led to a selection of 34 screened records. In the following wave the full-text articles were assessed for eligibility. During this procedure the inclusion and exclusion criteria were brought to bear. Ten articles were precluded immediately, because they did not met the age prerequisite. They were dealing with adolescents, young people or adults. Besides, eight articles had to be removed on the basis of their objectives and targets of measurements. This means that three of the eight aimed to determine the motivation, personal experience and self-efficacy with respect to game-play, and two of the eight aimed at a facilitation of communication or addressed the usability of platforms instead of therapeutic means. Further, two of these eight articles were not specify directed towards cerebral palsy, but towards a general health improvement of motor disorders or on parents perception of the health games for their child. The last one used robotic rehabilitation as main topic and did not focus on cerebral palsy predominantly. Furthermore two articles were reviews and consequently do not fit into the selection-criteria. At least, one study did not provide functional parameters, but was only verifying the task difficulty and summarizing the design of the intervention. Altogether 21 articles were excluded because of their irrelevance for this study purpose. This led to a final outcome of 13 suited studies, which provided the foundation for the analysis and synthetized all the information that can be gathered from the studies.

Data extraction and analysis

The study´s purpose was not placed on giving preference to one kind of treatment, but to highlight and identify the characteristics of game-interventions as a possibility for further treatment procedures. In order to do this, it was important to get an insight into the next aspects: the intervention characteristics, the game characteristics, the measurements, the advantages and limitations and the effectiveness of the intervention.

Intervention and study characteristics

First of all a summary of the intervention and study characteristics will be given. This includes a brief presentation of the study design, the target group, target behavior and the intervention set-up. By this, various different conditions under which the intervention was implemented were examined. The following points had to be mentioned:

- *Study design:* This category consists of data about article type, such as an experiment. Noting the study design will give an initial impression of the investigational actions that were made in the different experimental designs.
- *Intervention set up:* This group is subcategorized into the duration and number of interventions and the intended setting of the intervention. The first category contains the time of the intervention sessions and it lists the number of executed interventions. The second category includes the environmental aspects of the intervention. There will be determined whether the children are considered “playing individually“, in a “therapy session” or in a “laboratory session“. This is dependent on the presence of the parents, a

therapist and other patients. It also predisposed by the location where the intervention takes place, such as at home or at therapeutic praxis.

- *Target group:* This topic this includes a description of the participating groups will be given. To make a comparison of the study-results easier the participants will be classified on basis of their location of primary motor disability and types of tone abnormality. According to Wu, Croen, Shah, Newman and Najjar (2006) children with cerebral palsy were traditionally grouped into phenotypic subtypes. The functional motor impairments include a combination of the following subtypes: the degree of involvement of the body (mono-, hemi-, di- and quadriplegia) and the tonus of the motor type (spasticity, dyskinesia and ataxia).
- *Target skills:* It is important to note which impairment of cerebral palsy the intervention is aiming to alter by the game. This differs from the measurement in the respect that the measurements often assess more data to get additional data for explanations.

Game characteristics

In this category each used game is presented. They will be evaluated on their used technology and platforms and their gaming aspects.

- *Used technology:* This should be understood as device on which the chosen game is operating. With other words the platform will be given here (e.g. Wii, Xbox360, etc.). This information is typically seen in the "methods" section of the evaluated article.
- *Gamedesign-elements:* The content of this category is a profound description of the game-method design used in the respective interventions. According to Reeves´s and Read´s (2009) gamification taxonomy the game´s set-up can be coded among whether or not an ingredient from the taxonomy is present. The use of this instrument will lead to a more structured summary of the given game-methods. The so called „Ten ingredients of great games" created by Reeve and Read are shown in table 1 on the following page.

Table 1: Code scheme for "Ten ingredients of great games"

Code	Ingredient of great games
1	Self-Representations with Avatars
2	Three-Dimensional Environments
3	Narrative Context
4	Feedback
5	Reputations, Ranks and Levels
6	Marketplace and Economies
7	Competition under Rules that are Explicit and Enforced
8	Teams
9	Parallel Communication Systems
10	Time Pressure

Measurements

In this section a summary of the data that will be revealed by the article is given. It addresses the form of functional outcome measures and the used measuring instruments. Information over this is usually found in the "method" section of the reviewed study.

- *Measurements:* In this section all measurements are listed. This includes information about the data that will be obtained (qualitative and quantitative) through the outcome measures.
- *Method of measurements:* This category contains information about the measuring instruments of the selected interventions. This will lead to a summary on the sort of data and the tools that were used for the obtainment and assessment. For example the type of the used test for the experimental research is mentioned here.

Evaluation

In this section important advantages and limitation that can be derived from the reviewed articles will be named. The information about the two subsections, major advantages as well as disadvantages, can be extracted out the article sections "outcome" and "discussion". In some cases information about the disadvantages of the respective studies was found in the "limitation" section.

- *Major Advantages:* This third category of game characteristics includes the advantages regarding the integration of games for the physical health promotion of children with cerebral palsy.
- *Restrictions and constraints:* To this category belong limitations that occurred while running the intervention and game-process. This restriction can arise due to the structure of the intervention and design of the game. Through this trouble may ask for adjustment during the game process or problems could be encountered within the game-play self.

Effectiveness

The effectiveness of the 15 intervention will be examined with the aid of a method derived from the work of Morrison, Yardley, Powell and Michie (2012). Morrison et al. (2012) applied general criteria to the outcome measures for defining the effectiveness of an intervention, as listed in *Table 2*. In order to gain insight in the great variety of the effect of design features the interventions are coded as either "more effective", "less effective" or "ineffective". But the effectiveness of some studies is not investigated yet, due to the just recently arisen awareness of gamification in the health care sector. These intervention will get the encoding "no measures available". However, some interventions only providing a pilot study often deliver additional investigation. If this data is accessible in the results of the intervention, it will be mentioned under the citation "additional data". This coding-system eases comparisons between the different forms of functional outcomes of the studies.

Table 2. Criteria for defining intervention effectiveness, according to Morrison et al. (2012)

Intervention code	Criteria
More effective	- The intervention led to improvement on the *majority* of outcome measures - The intervention was at least *as effective* as comparison group - The intervention was *more effective* than waiting list or no intervention control group
Less effective	- The intervention led to improvement on a *minority* of outcomes measures - The intervention was *not necessarily as effective* as comparison groups - The intervention was *more effective* than waiting list or no intervention control group
Ineffective	- The intervention *did not lead to improvement* in any of the outcome measures - The intervention was *no more effective* than waiting list or no intervention control groups

Results

The derivation of the articles under the exclusion and inclusion criteria resulted in a final outcome of 13 publications. A short description of the selected publications is presented in Table 3. This table provides additional information on the authors, the titles, the year and the country of the articles. In order to ease the subsequent investigation of the interventions, each publication will be labeled with an explicit code. This code will be used for referencing in the following elaboration and will simplify comparisons between interventions.

Table. 3: Overview of included interventions

Authors of article	Title of publication	Year and Country of publication	Intervention code
Burdea, G. C., Cioi, D., Kale, A., Janes, W. E., Ross, S. A. & Engsberg, J. R.	*Robotics and gaming to improve ankle strength, motor control, and function in children with cerebral palsy – A case study series*	2013, United States	I1
Burdea, G. C., Jain, A., Rabin, B., Pellosie, R. & Golomb, M.	*Long-term hand tele-rehabilitation on the playstation 3: Benefits and challenges*	2011, United States (MA)	I2
Gordon, C., Roopchand-Martin, S. & Gregg, A.	*Potential of the Nintendo Wii™ as a rehabilitation tool for children with cerebral palsy in a developing country: a pilot study*	2012, Jamaica	I3
Henschke, M., Hobbs, D. & Wilkinson, B.	*Developing serious games for children with cerebral palsy: Case study and pilot trail*	2012, Australia	I4
Howcroft, J., Klejman, S., Fehlings, D., Wright, V., Zabjek, K., Andrysek, J. & Biddiss, E.	*Active Video Game Paly in Children With Cerebral Palsy: Potential for Physical Activity Promotion and Rehabilitation Therapies*	2012, Canada (ON)	I5
Jannink, M. J. A., Van Der Wilden, G. J., Navis, D. W., Visser, G., Gussinklo, J. & Ijzerman, M.	*A low-cost video game applied for training of upper extremity function in children with cerebral palsy: A pilot study*	2008, Netherlands	I6
Jelsma, J., Pronk, M., Ferguson, G. & Jelsma-Smit, D.	*The effect of the Nintendo Wii Fit on balance control and gross motor function of children with spastic hemiplegic cerebral palsy*	2013, United Kingdom	I7

Ramstrand, N. & Lygnegard, F.	*Can balance in children with cerebral palsy improve trough use of an activity promoting computer game?*	2012, Sweden	I8
Reid, D. T.	*The use of virtual reality to improve upper-extremity efficiency skills in children with cerebral palsy: a pilot study*	2002, Canada	I9
Robert, M., Ballaz, L., Hart, R. & Lemay, M.	*Exercise Intensity Levels in Children with Cerebral Palsy While Playing with an Active Video Game Console*	2013, Canada	I10
Sandlund, M., Waterworth, E.L., & Häger, C.	*Using motion interactive games to promote physical activity and enhance motor performance in children with CP*	2011, Sweden	I11
Wade, W. & Porter, D.	*Sitting playfully: Does the use of a centre of gravity computer game controller influence the sitting ability of young people with cerebral palsy?*	2012, United Kingdom	I12
Yong, C. H., Wei R. F. M., Aimei, M. K., Yanting, P., Shan, C. P., Leng, M. N. Y. & Kumar, D. S.	*Effects of virtual reality games with physiotherapy on balance of children with cerebral palsy*	2011, Singapore	I13

It becomes apparent from the Table 3 that the list of the found literature concerned recent studies. The publication years ranged from 2002 to 2013. Three of the 12 are published in Canada, two in the United States, further two in Sweden and two in the United Kingdom. The five remaining articles were published in Jamaica, Australia, Netherlands and Singapore. The author G. C. Burdea wrote together with other authors two of the articles. With regard to the other publication no overlaps were found in the authors.

The data-extraction took place based on the found literature. To end up in a completed analysis of the articles, the intervention characteristics and game characteristics had to be examined and the effectiveness had to be evaluated. The most important results of the whole elaborations is summarized in Table 9 (see page 25-29).

Findings in intervention characteristics

Referring to the study design it was evident that four studies are pilot studies (I3, I4, I6 and I9). Three articles included case or feasibility studies with a pre- and post-test design (I1, I2 and I11) and further two included randomized controlled trials (I8 and I13). The remaining studies were set up as a single group experimental design (I5), as single subject, single blinded experiment (I7), as cross-sectional trial (I10) or as randomized cross-over trial (I12). Three interventions (I6, I10 and I13) worked with control conditions in which participants received another physical therapy different form the experimental condition or no therapy.

The category intervention set up could be subcategorized in the intended time investment (duration) and the intended location (setting). The time periods of the conducted interventions were wide-ranging varying between one day and 14 month. In I5 and I10 each 5 sessions were carried out and were evaluated within one day. Most interventions (I3, I4, I6, I7, I8, I9 and I11) had a duration between 2 weeks to 8 weeks and were split up in multiple sessions. The number of sessions varied between 2 sessions a week and 7 sessions a week. Three of the thirteen interventions (I1, I2, I12 and I13) lasted 12 weeks or longer. Concerning the intended setting of the interventions, 7 studies (I2, I4, I7, I8, I9, I11 and I12) were based on home therapy programs and the remaining 6 studies used laboratory settings to ensure a controlled research. All laboratory studies were conducted under constant supervision of a therapist or an interventionists. I1, I11 and I12 were special in the kind of involved persons. These exceptional interventions also entangled the parents or school staff with the process of implementation. Opposite, the home based games were played individually without direct supervision in the most cases (I2, I4, I7, I8, I9 and I11). An overview of the intervention set up is seen in table 4.

Table 4: Intervention set up

Inter-vention	Time investment			Intended setting	
	Duration	Sessions	Session times/ periods	Location	Involved persons
I1	12 weeks	3 sessions/week	40 minutes	research laboratory (university)	Therapists supervision, parental report
I2	14 & 6 month	>56 sessions		Home-based therapy	Individual play
I3	6 weeks	2 sessions/week	45 minutes	clinical laboratory setting (rehabilitation centre)	Physical therapists
I4	2 weeks	Variations for all 9 games	Variations for all 9 games	Home-based therapy	Individual play
I5		4 sessions	8 minutes	laboratory setting (urban rehabilitation hospital)	Interventionist and experimenter
I6	6 weeks	2 sessions/week	30 minutes	Laboratory setting (rehabilitation hospital)	Physiotherapist
I7	3 weeks		25 minutes	Home-based therapy	Individual play
I8	5 weeks	5 sessions/week	30 minutes	Home-based therapy	Individual play
I9	8 weeks	1 session/week	90 minutes	Home-based therapy	Individual play
I10		4 sessions	40 minutes	laboratory setting	Interventionist
I11	4 weeks	1 session/ day	> 20 minutes	Home-based therapy	Parents, group or individual paly
I12	2 x 3 month			Home/School-based therapy	Interventionists, school staff
I13	12 weeks	1 session/week	20 minutes	physiotherapy setting	Physiotherapist, Interventionist

All interventions focused on children with cerebral palsy in general. However the studies varied in their concentration on specific subtypes of cerebral palsy. Two of the thirteen interventions were dealing with children suffering from spastic hemiplegia of cerebral palsy (I2, I7). Most of the interventions focused on children with spasticity (I6, I9, I10 and I11) and/or hemiplegia (I3, I4, I5, I6, I8 and I12). Beside six interventions were directed at children with diplegia (I3, I5, I6, I8, I9 and I10). Two of these interventions were directed at children with diplegia and hemiplegia without making any specification of the tone abnormality (I5, I8). Every intervention which was also concentrated on quadriplegia, dealt at least with one further subtype (I3, I6, I9 and I12). A unique case constituted the third intervention, which only included children with a dyskinetic muscle tone. Besides, only one intervention concentrated on all types of tone abnormality without making a specification of the location of the primary motor disability (I11). Thereby this was the solitary intervention directed at the ataxic subtypes. As well I1 as I13 did not mention any specific subtype of cerebral palsy cases. The finding derived in the category of the target group were represented in the following table 5.

Table 5: Specific Subtypes of Cerebral Palsy

Inter-vention	Spastic*	Dyskinetic*	Ataxic*	Monoplegia**	Diplegia**	Hemiplegia**	Quadriplegia**
	1	2	3	4	5	6	7
I1	NS [1]	NS	NS	NS	NS	NS	NS
I2	X [2]	— [3]	—	—	—	X	—
I3	—	X	—	—	X	X	X
I4	NS	NS	NS	—	—	X	—
I5	NS	NS	NS	—	X	X	—
I6	X	—	—	—	X	X	X
I7	X	—	—	—	—	X	—
I8	NS	NS	NS	—	X	X	—
I9	X	—	—	—	X	—	X
I10	X	—	—	—	X	—	—
I11	X	X	X	NS	NS	NS	NS
I12	NS	NS	NS	—	—	X	X
I13	NS	NS	NS	NS	NS	NS	NS

[1] NS is a shortcut for not specified
[2] X indicates an inclusion of the subtype
[3] indicates an exclusion of the stubtype
** Type of tone abnormality according to Wu et al. (2006)*
*** Location of primary motor disability according to Wu et al. (2006)*

Table 6 summarizes the results of the target skills. While all interventions were commonly directed at assessing the effectiveness and utility of games as a tool for rehabilitation and treatment elements of cerebral palsy, the interventions differed in their focus of the targeted behavior. The first intervention, I1 was directed at lower extremity function, motor performance and muscle activation. While I2 took only muscle activation/ strength has main target skill, I3 and I10 concentrated both on motor performance and muscle activation or strengths. Furthermore, I5, I6, I9 and I11 resembled each other in their focus on upper-limb extremities within the intervention. These studies were also aiming to alter at least one second skill, such as the motor performance and/or kinematic function of the subjects. Three studies were mainly directed at assessing the balance after the intervention-sessions (I7, I8 and I13). At last, I12 was merely directed at the sitting ability of children with cerebral palsy.

Table 6: Target skills

Inter-vention	Balance	Upper-limb extremities	Lower extremities	Motor performance/ kinematics	Muscle Activation/ Strength	Motivation/ Satisfaction	Others
	1	2	3	4	5	6	7
I1	—	—	X	X	X	—	quality of life
I2	—	—	—	—	X	—	dexterity of hand function & bone health
I3	—	—	—	X	X	—	
I4	—	—	—	—	X	X	replay value
I5	—	X	—	X	X	X	
I6	—	X	—	—	—	X	
I7	X	—	—	—	—	—	Running speed & agility
I8	X	—	—	—	—	—	
I9	—	X	—	—	X	—	Mobility
I10	—	—	—	X	X	X	Heart rate, range of motion, spasticity, Exercise intensity
I11	—	X	—	X	—	—	
I12	—	—	—	—	—	—	Sitting ability
I13	X	—	—	—	—	X	

Findings in game characteristics

Nearly all game-methods within the interventions could be noted as serious games, which already existed. However one exception created the fourth intervention, which made use of nine off-the-shelf video games. Mostly the interventions related on video game consoles. The most branded and used consoles are the Wii™ released by Nintendo, the PlayStation® from Sony and Microsoft´s Xbox 360. Those platforms allowed the child to watch him- of herself on the screen without wearing any equipment. Six interventions used the Wii™ console with different game applications, namely Wii Fit (I7, I8, I10 and I13) or Wii Sports (I3, I5). The game Wii Fit took advantage of a balance board to exercise the balance. The Wii game Sporty used a wireless controller, which could track its position in a 3D space. Three other studies of which two intervention implemented the EyeToy-Play (I6 and I11) for the Sony Playstation® (I2). This video-capture technique could only detect movements in one plane and not in depth. The Standard Xbox360 installed on an entertainment notebook was used in I4. This technology used a game controller. The user stood or sat facing the screen where the game environment was displayed. The lasting interventions aimed to train physical skills by the Rutger Ankle CP system (I1), by an IREX system with mandala gesture Xtreme technology (I9) or by a specially made sitting platform which could detect changes in the distribution of pressure (I12).
An evaluation of the game ingredients was resulting in table 7. It has to be noted that none of the interventions made use of the game ingredient ´Marketplace and Economies`. Almost all games used an avatar as central feature to represent the subjects within the media. The twelfth intervention constituted an exception for the reason that its game only met the game ingredient ´ranks and levels` and `explicit rules for competition`. Likewise all other intervention made ranks, levels and rules available. Regardless the intervention 12, the entire range of intervention games gave quantitative feedback to the player. The fulfilment or failure realization of the remaining game ingredients can be looked up in the ensuing table.

Table 7: Game Ingredients of great games

	Games	Avatar	3D Envir-onment	Narrative Context	Feed-back	Ranks, Levels	Mar-ket-place	Compe-tition	Teams	Commu-nication	Time Pressur e
		1	2	3	4	5	6	7	8	9	10
I1	Airplane & Breakout 3D game	X	—/ X	—	X	X	—	X	—	X	X
I2	UFO & Sliders	X	—	X/ —	X	X	—	X	—	—	—
I3	Boxing, Baseball & Tennis	X	—	—	X	X	—	X	—	X	—
I4	Space Stuntz, Biplane 1922, etc.	X	X	X	X	X	—	X	—	X	X
I5	Bowling, Tennis, Boxing & Dancing	X	—	—	X	X	—	X	X	X	—
I6	EyeToy minigames	X	—	—	X	X	—	X	—	—	X
I7	Snow-boarding, Skiing, Soccer etc.	X	—	—	X	X	—	X	—	—	—
I8	Wii Fit games	X	—	—	X	X	—	X	—	—	—
I9	Orbosity, Drums, Paint, Volleyball, Soccer	X	—	—	X	X	—	X	—	—	—
I10	Jogging, Bicycling, Snow-boarding & Skiing	X	—	—	X	X	—	X	—	—	—
I11	EyeToy Play 3	X	—	—	X	X	—	X	—	—	X
I12	Computer games (e.g. Pac-Man)	—	—	—	—	X	—	X	—	—	—
I13	Wii Fit games	X	—	—	X	X	—	X	—	—	—

Advantages and Limitations

The most common revealed advantage of the interventions was a high motivation of the children to participate and engage in the therapy program (I3, I4, I5, I11 and I13). The motivation was measured by questionnaires or was extracted out of the game diaries by the experimenter. Furthermore was the readily availability of low-cost tools a benefit for the interventions (I2, I8 and I10). It was also important to remark the great adaptability of the games to the ability of the children (I3, I4, I5 and I8).

Similarly some limitations were more often encountered than others. This suggested that the implementation of game elements into a physical therapy program was going along with some major restrictions and constraints. To this belonged technological limits (I2, I4, I5, I6, I7, I11 and I12), needed assistance and encouragement from therapist or parents to maintain the therapy (I1, I2 and I13) and needed equipment (I5), which made a generalization to natural settings difficult. Furthermore, other often mentioned restrictions were too small sample sizes (I1, I3, I4, I5, I7, I9, I10 and I13), a lack of a comparative groups (I1, I3, I7 and I9), selection biases (I3 and I7) and an absence of blinding of the experimenter (I1 and I3). Sometimes the subjects of the intervention were contemporaneous partaking another therapy (I1 and I13), whereby the detected effects could not only be attributed to the intervention.

Effectiveness

While assessing the literature for the effectiveness according to Morrison et al. (2012) it was found that six intervention were ´more effective` (I1, I2, I3, I9, I11 and I12), three intervention were ´less effective` (I5, I6 and I7) and three interventions were coded with ´ineffective` (I8, I10 and I13). The reasons for this outline can be seen in Table 8. With regard to intervention 4, no investigation was possible because of an inaccessibility of measures.

Table 8: Effectiveness with reason

Inter-vention	Effectiveness	Reason
I1	More effective	Gait function improved substantially in ankle kinematic, speed and endurance, GMFM indicated improvements Game performance improved Strenght increases in 5 cases for maximum DF and PF torques
I2	More effective	Strength improved 50 %, good progress in hand function (faster and able to perform all standardized tasks) Substantial improvement in mineral content of plegic forearm bone
I3	More effective	Improvement in mean GMFM (increase from 62.83 to 10.17) All chances were note to be above the minimal clinically important difference for the scale
I4	Unknown	No results to compare (only one participant) and impossible to classify the outcome measures due to the mainly qualitative design
I5	Less effective	Moderate levels of physical activity were achieved during dance and boxing games. Muscle activation did not exceed maximum voluntary exertions. Angular velocities and accelerations were significantly larger in the dominant arm than in the hemiplegic arm during bilateral play. All energy measures were significantly lower for the baseline state than during AVG play.
I6	Less effective	2 of 5 children improved their arm functions
I7	Less effective	Balance score improved significantly, but running speed and agility (TUDS) did not significantly improve
I8	Ineffective	No significant improvements in balance, no differences in onset latency of lower leg muscle (reactive balance test) or in the rhythmic weight shift test
I9	More effective	2 of 4 children showed clinical significant improvements: Improvement on the QUEST All showed improvement on BOTMP-item “touching a swinging ball”
I10	Ineffective	No differences in outcome measures between groups
I11	More effective	Motor performance slightly improved (mABC, subtest: manual dexterity) No significant results for One Minute Walk Test nor for BOTMP (upper limb coordination), however physical activity improved
I12	More effective	Improvements at some of the postural components of the Chailey sitting ability scale, specifically spinal profile and shoulder girdle position Proximal sitting stability during reaching and the overall quality of reaching were improved SACND: statistically significant increase in overall scores for rest and reach
I13	Ineffective	All dependent variables of control and experimental groups were not statistically significant (sometimes even control group showed better improvements)

Table 9: Data extraction table derived from categorical analysis

	Intervention characteristics	Game characteristics	Measurements and Methods of measurements	Advantages and Limitations	Effectiveness according to Morrison et al. (2012)
I1	**Study design:** Case study series **Target group:** 3 children (age 7-12 years) **Target skills:** lower extremities (gait function) **Intervention set up**: *Duration:* 12 weeks (3 times/week = 36 rehabilitation sessions) number, *Intended setting*: university research laboratory	**Used technology:** Rutgers robotic Ankle CP system **Game design elements****: 1, 2, 4, 5, 9, 10	**Measurements:** Impairment Overall function/gait function Quality of life **Method of measurement:** (1) DF/PF torques, dorsiflexion initial contact angle & gait speed (2) The Gross Motor Function Measure (GMFM) (3) Peadiatric Quality of Life Inventory (Peds QL) (4) Game Score	**Restrictions and constraints:** - Small number of subjects, - Lack of follow up study, - Lack of control group, - Therapist, performing clinical evaluation, not blinded to training protocol , - Sessions require direct supervision for setup and progression of each game depending on performance - Any initial therapy of children continued during experimental intervention - user comfort may suffer from equipment	More effective
I2	**Study design**: feasibility study **Target group**: 2 children *Specific Subtype*:* 1, 6 **Target skills:** hand function **Intervention set up**: *Duration*: one subject 14 month and the other 6 month *Intended setting:* home therapy	**Used technology:** PlayStation 3; 5DT sensing gloves **Game design elements**:** 1, 3, 4, 5, 7	**Measurements**: Grasp strength & dexterity of hand function bone health **Method of measurement:** (1) Jamar dynamometer, (2) Jebsen test of hand function (3) Bone health measurements	**Advantages:** - low-cost tool offers great opportunity for home- use **Restrictions and constraints:** - Technological limits (gloves need calibration, dislodge when taken off, complicate data analysis, internet connection, needs power) - Family encouragement need for maintenance small sample size	More effective
I3	**Study design:** pilot study with pre-post-test design **Target group:** 6 children (6-12 years) *Specific Subtype*:* 2, 5, 6, 7 **Target skills:** motor control **Intervention set up:** *Duration:* 6 weeks (45 min. periods, 2x week)	**Used technology:** Nintendo Wii^{TM} Sports **Game design elements**:** 1, 4, 5, 7, 9	**Measurements:** Gross motor function **Method of measurement:** (1) Gross Motor Function Measure (GMFM)	**Advantages:** - Excellent psychometric quality - All participants able to attend and complete sessions - No participation in additional therapies **Restrictions and constraints:** - Lack of comparative group - No concrete conclusions possible (small sample size, clinical trials required) - Selection bias (convenience sampling)	More effective

	Intended setting: clinical laboratory			- Assessor not blinded (decrease internal validity)	
I4	**Study design**: case study and pilot trial **Target group:** 1 pre-teen girl *Specific subtype:* 6 **Target skills**: physical activity **Intervention set up:** *Duration:* 2 weeks *Intended setting:* Home therapy	**Used technology:** Standard Xbox360 USB controller **Game design elements**:** 1, 2, 3, 4, 5, 7, 9, 10	**Measurements:** Engagement Replay value, Entertainment **Method of measurements:** (1) Questionnaire for ease of accessibility, enjoyment and longevity (2) Game metrics measuring session length and frequency	**Advantages:** - Games were flexible, enjoyable and cognitively engaging to make them as effective for the intended application in home-based therapies **Restriction and constraints:** - One study subject – no conclusion possible - Limitations in interface and controls at high level difficulty	Unknown, no results to compare
I5	**Study design:** Single-group experimental design **Target group:** 17 children (age 7- 10 years *Specific Subtype*:* 5, 6 **Target skills:** movement control, muscle activation **Intervention set up:** *Duration:* 8 min. play for each of the game, rest periods of 5 minutes; *Intended setting:* laboratory setting in rehabilitation hospital	**Used technology:** Nintendo Wii Sports and equipment for sEMG and DAQ **Game design elements****: 1, 4, 5, 7, 8, 9	**Measurements:** Upper limb muscle activations Upper limb kinematics Self-report enjoyment **Method of measurement:** (1) Portable cardiopulmonary testing unit (2) Surface electromyography (3) Optical motion capture system (4) Physical activity Enjoyment Scale (PACES)	**Advantages:** - Games encourage repetitive movement of varying frequencies from low to high - Potential for neuromuscular reeducation in home therapy - Great adaptability in intensity of physical activity and movement frequency **Restriction and constraints:** - No generalization to natural home settings (equipment and observer) - Low sample size (low validity) - Equation used to calculate EE based on adults data - Fixed level of play may reduce energy & muscle activation level - No measurement of long-term efficacy	Less effective
I6	**Study design:** Pilot study **Target group:** 12 children (mean age 11 years, 9 month) *Specific Subtype*:* 1, 5, 6, 7 **Target skills:** Arm- and hand control **Intervention set up:** *Duration*: 6 weeks (30 min., 2x week)	**Used technology**: EyeToy-Play minigames **Game design elements****: 1, 4, 5, 7, 10	**Measurements:** User satisfaction Upper limb function **Method of measurement:** (1) User satisfaction questionnaire (2) The Melbourne Assessment of Unilateral Upper Limb Function	**Advantages:** - No negative side effects reported and children were satisfied with the EyeToy training **Restrictions and constraints:** - Technology not designed with a rehabilitation purpose, not all desired adjustments can be made	Less effective

	Intended setting: rehabilitation hospital				
I7	**Study design:** A single-subject single blinded study **Target group:** 14 children (age 6-12 years) *Specific Subtype*:* 1,5,6 **Target skills:** balance **Intervention set-up:** *Duration*: 3 weeks (25 minutes) *Intended setting*: home-based	**Used technology:** Interactive video gaming (IVG) – Nintendo Wii Fit **Game design elements****: 1, 4, 5, 7	**Measurements:** Balance Running speed and agility **Method of measurement:** (1) Bruininks-Oseretsky Test of Motor Proficiency-2 (BOTMP-2) (2) Timed Up and Down Stairs (TUDS)	**Advantages:** - Repeated measures throughout study - No additional therapies during intervention, **Restrictions and constraints:** - No comparison intervention and small sample size - Wii based training not as primary means for rehabilitation - Limited generalization to broad population - Selection bias	Less effective
I8	**Study design:** A randomized controlled trial **Target group:** 18 children (age 8-17 years) *Specific Subtype*:* 5, 6 **Target skills:** balance **Intervention set up:** *Duration:* 5 weeks (min 30 minutes a day, 5 days a week) *Intended setting*: home based	**Used technology:** Nintendo Wii Fit, Wii Balance Board **Game design elements**:** 1, 4, 5, 7	**Measurements**: Standing & Reactive balance, Weight shifting ability (directional control and synchronization of movement) **Method of measurement:** (1) The modified sensory organization test (2) Reactive balance test (3) Rhythmic weight shift test	**Advantages:** - Low-cost, readily available platform - Levels are adaptable to children´s ability	Ineffective
I9	**Study design:** a pilot study **Target group:** 4 children (age 8-12 years) *Specific Subtype*:* 1, 5, 7 **Target skills**: promote upper extremity range of motion, mobility and strength **Intervention set up:** *Duration:* 8 weeks, 1 x 90 min session a week *Intended setting:* Home-based	**Used technology:** IREX system: Mandala gesture Xtreme technology and video camera as capturing/ tracking device **Game design elements**:** 1, 4, 5, 7	**Measurements:** Upper extremity control **Method of measurements:** (1) Quality of Upper Extremity Skills Test (QUEST) (2) Bruininks-Oseretsky Test of Motor Proficiency (BOTMP) (3) Average percent accuracy score (2 of 4 showed noteable improvements)	**Advantages:** - Offers promising preliminary data on the effectiveness of IREX in upper-extrimity rehabilitation **Restrictions and constraints:** - Small sample size - No comparable group	More effective

I10	**Study design:** cross-sectional study **Target group:** 10 children (age 7-12 years) *Specific Subtype*:* 1, 5 **Target skills:** physical activity, strength **Intervention set up:** *Duration:* 40 min/ game *Intended setting:* laboratory setting	**Used technology:** Active video game console Wii Fit **Game design elements**:** 1, 4, 5, 7	**Measurements**: Heart rate, range of motion, spasticity, maximal strength Kinematic function, Exercise intensity, Motivation **Method of measurements:** (1) Heart rate belt (Polar RS400) (2) Lower extremity motion analysis by 8-camera motion capture system (3) Borg scale	**Advantages:** - Children with CP obtain exercise-related benefits similar to those obtained by children without CP - Use of low-cost, safe, readily available and efficient tool - Comparable group of same age **Restrictions and constraints:** - Relatively small and heterogeneous sample	Ineffective
I11	**Study design:** feasibility study **Target group:** 14 children with CP (6-16 years) *Specific Subtype*:* 1, 2, 3 **Target skills:** goal-directed arm movements **Intervention set up:** *Duration:* 4 weeks, > 20 minutes / day *Intended setting:* Home-based	**Used technology:** Eye Toy game Play3 for Sony Palystation2® **Game design elements**:** 1, 4, 5, 7, 10	**Measurements:** General motor performance; Upper limb coordination Intensity of practice **Method of measurements:** (1) SenseWear Pro3 Armband (2) Bruininks-Oseretsky Test of Motor Proficiency 5:6 (BOTMP) (3) Movement Assessment Battery for Children 2 (mABC-2) (4) One Minute Walk Test (5) Gaming-diaries	**Advantages:** - Children showed high motivation to practice **Restrictions and constraints**: - Activity monitors have not been validated to measure energy expenditure under free-living conditions; - Data-loss - Short measurement (6 weeks minimum time) periods, - Floor- and ceiling effects	More effective
I12	**Study design:** A randomized cross-over trial **Target group:** 13 children (age 7-16 years) **Target skills:** sitting ability **Intervention set up:** *Duration:* 2 times for three month *Intended setting:* Home therapy	**Used technology:** Computer games controlled using a sitting platform (detects changes in distribution of pressure) **Game design elements**:** 5, 7	**Measurements:** Sitting ability Functional reach and posture **Methods of measurements:** (1) Chailey Levels of Ability (2) Sitting Assessment for Children with Neuromotor Dysfunction (SACND) (3) Test of Playfullness	**Advantages:** - Two groups: receiving intervention /no intervention & intervention/ no intervention - Study opened up initial area for recruitment in entire South of England & recruitment through schools: Useful to staff to engage students in activity that was not accessible to individuals **Restriction and constraints:** - Some difficulties with equipment in homes (time to set up equipment & assistance for child)	More effective

			(4) Diary about amount of usage	- Raises questions as to the components that constitute sitting ability	
I13	**Study design:** experimental study **Target group:** 12 children (mean age: 11.2 years) **Target skills:** balance **Study set up:** *Duration:* 12 weeks, 20 min session/week *Intended setting:* physiotherapy setting,	**Used technology:** Nintendo Wii balance board **Game design elements**:** 1, 4, 5, 7	**Measurements:** Amount of displacement of postural sway in static stance / sitting Dynamic balance Motivation **Method of measurements:** (1) Postural sway (2) Functional reach test (FRT) (3) Timed-Up-and-Go Test (TUG) (4) Activities-specific balance confidence (ABC)	**Advantages:** - Fun to use, interactive and encourages participation **Restrictions and constraints:** - Intervention in addition to conventional physiotherapy - Larger trail with higher dosage of Wii games needed to draw definitive conclusion - Decrease in motivation at post-intervention	Ineffective

** A description of the specific subtypes of cerebral palsy within the target group is seen in Table 5.*

*** A description of the game elements is given in Table 7.*

Discussion

Game-based technological therapy approaches are recently emerging as a form of rehabilitation therapy. Due to its novelty little has been done to review the studies applying gamification in therapies for children suffering from cerebral palsy. A comprehensive literature search is aimed at a summary of the state of the scientific work that was done in the field of integrating game-related methods. It is used in order to evaluate their overall feasibility for the cerebral palsy treatments.

A collection of 13 relevant articles, which are divided under the exclusion and inclusion criteria, is derived from a previous obtained database (EndNote library). Most of the selected studies are pilot, case or feasibility studies with only a small number of participants included in the research. Overall the total number of participants is 131 ranging from 6 to 17 years. Few studies with small samples are typical for first investigations of a novel research field. If these early studies are valuable, they will trigger larger pooled and well controlled studies (Leon, Davis & Kraemer, 2011). Important findings of the studies are obtained from an examination of the initial review-questions, which will be discussed in a comprehensive way. It is found that even though the study design of the intervention has a lot of limitations, they yield important information for future research.

Main findings

The protocols of the interventions are different from one study to the other. More specifically, next to different methods for outcome measurement, other methodological dissimilarities are found in the frequency of the intervention, the number of sessions, their duration, the type of intervention and the used game.

First of all, it has to be mentioned that the studies rarely substantiate the decisions that are made in the designing process of the interventions. Besides, there is no broad consensus between the interventions referring to the duration and the location of the therapy program. O'Neil, Fragala-Pinkham, Westcott, Martin, Chiarello, Valvano and Rose (2006) developed a general recommendation for clinical management of children with cerebral palsy from 6 to 21 years. A therapeutic program should last at minimum 10 weeks with two or three sessions a week. Indeed, four of the interventions last 10 weeks or longer (I1, I2, I12 and I13), but only one of them meets the requirements of the amount of sessions per week (I1). Most of the interventions do not fulfil the requisition and extend only up to eight weeks. These findings correspond to the conclusions made by Martin, Baker and Harvey (2010). They claim that the evidence in the recent literature does not support a definite length for a therapy. Therefore the question remains as to whether a standard intervention duration is necessary. This review does not allow to determine the best frequency and duration of a rehabilitation program, because the effectiveness of the intervention is unrelated to the duration based on the results of this review.

Likewise irregularities are seen in the selected locations of the given interventions. Six interventions chose fixed, external locations, wherein the implementation of the game method can be controlled. Seven interventions used home-based or school-setting. In this review a preference to one of the chosen settings cannot be given because the effectiveness of the interventions are not different with respect to the duration or the setting. According to Ideishi, O´Neil, Chiarello and Nixon-Cave (2010) physical therapist should give therapy across different environmental settings to ensure a generalization of skills. The given intervention did not meet this necessity and a generalization was therefore not warranted. It will be interesting to see whether a spread of the game-therapy across different location actually has an impact in everyday situations of children with cerebral palsy. Further research on therapy programs following the request of multiple locations, may even find more effective results than given in these studies.

The target groups of the interventions differ a lot in the specific subtypes of cerebral palsy making them heterogeneous samples. However, a common trend towards an investigation of the spastic type in hemiplegic cerebral palsy is seen. This tendency can be attributed to the fact that this subtype is more frequent in the population of cerebral palsy (Jones et al., 2007). From the results can be retrieved that especially the type of tone abnormality relates to the type of the target behavior. If the sample consists of children with cerebral palsy of the spastic type, the interventions are more often directed at upper-limb control or muscle activation. Whereas motor performance and kinematics are more frequently addressed by children with dyskinesia. It is logically inferential that the target behavior matches the types of tone abnormality. For example, it is important to teach dyskinetic children motor kinematics to prevent an atypical muscle tone causing an abnormal posture (Fairhurst, 2012).

The main tools that are used for the study purposes are commercial off-the-shelf games. Only Wade et al. (2012) developed a sitting platform as a serious game specifically for health improvements. The off-the-shelf games used in this context can be seen as “serious games” because the games are not intended to be played primarily for amusement. They have in these cases an explicit health-promoting intention (Ritterfeld et al., 2009). The general aim of the interventions is increasing the physical ability by proposing fitness-like exercises. All of the interventions implement technology that is not theoretically developed for therapeutic objectives, like the Nintendo Wii or the Sony Playstation. The authors reported the easy accessibility and low costs of the platforms to be the main reasons for their use. Mader, Natkin and Levieux (2012) would justify commercial games methods as well chosen because of their ability to promote motivation through the game-context and motivation seems to be a necessary condition for a change in behavior. Nevertheless, there are some disadvantages in using commercially available game consoles. They lack concise direction in exercise and do not have the needed adjust-ability to the different individual needs of the children with cerebral palsy (Henschke et al, 2012). Putting on extra equipment for measurement purposes and the presence of an experiment during the exercise regime may lead to a drop in user comfort giving a misleading account of the ´real` behavior during a therapy. These drawbacks of commercially available games lead to conflicting evidence of the outcomes of this review. The use of the games was effective in most cases, even though they are not well adjustable to the children’s needs. Sandlund, Hoshi, Lindh Waterworth and Häger-Ross (2009) see a high relevance in the deliberated development of new devices for therapies, which are compatible with commercial available games, but still add the desires training effect to the gaming activity. Compared with the results of this review the question raises if the game-technology really need to be more customable and adaptable.

The preference of a game changes in line with the abilities that are aimed to be altered. Therefore, not only the subtypes of cerebral palsy define the target behaviors to a certain degree, they also determine the types of game methods and elements that are used. Muscle activation most often aimed to alter by all technologies, except the sitting platform. The Nintendo Wii Fit software appears to be a convenient tool for enhancing balance and exercise mobility (I7, I8, I13). The IREX system works with mobility training too, but by enhancing muscle strength. The games of Wii Sports mostly aim to increase motor performance and muscle activation (I3, I5). The Eye-toy games of Sony are directed at upper limb extremity control and muscle activation (I2, I11).

Furthermore, the applied game elements within the used games were analyzed by the code of scheme of ´Ten ingredients of great games`. The results indicate a great similarity in the applied game elements. All of the game-methods make use of an *avatar* for a self-representation of the player. The virtual avatar makes it possible for the user to monitor his or her own activity. Likewise *ranks and levels* as well as *explicit rules of competition* were applied in all game-methods. Due to Deterding et al. (2011), rules create the basis of all games. They are needed to understand and win the game. Playing with strive towards goals under rules lead to an acquisition of new skills, which enable the player to reach new levels or ranks with altering intensities (Lepper et al., 1987). *Feedback*, which is mostly provided visually or audible by nearly all interventions, connects the player´s achievements to his or her competence level. The perceived competence enhances fun and intrinsic motivation the most, if the win can be related to own capabilities (Lepper et al., 1987; Ryan, Rigby & Przybylski, 2006). The feedback is often given across different sensory input because children with cerebral palsy can suffer from visible or audible impairments (Rosenbaum et al., 2007). According to Schmidt and Wrisberg (2004) feedback and goals have beneficial effects on children´s performance. Goals provide the necessary challenge for children and feedback about the movement pattern leads to changes in the fundamental structure of the generalized motor program. The ingredient *marketplace and economies* is never applied and the ingredients *teams*, *time pressure* and *narrative context* are used rarely. The choices of applied game elements are highly reasonable, concerning their suitability for children with cerebral palsy. It is not advised to use more challenge because children with cerebral palsy often lack a sufficient level of cognitive ability to deal with it. Besides, the patients are often unable to analyze a variety of sources. For example, rapid decision making has been often problematic for children with cerebral palsy (Horgan, 1980).

The output data were mostly measured using subjective self-reports (e.g. questionnaires or diaries) or a variety of standardized motor tests. On the one hand self-report measures are being low-cost and easy to administer. But on the other hand, validity problems can arise through considerable recall biases and are not suitable for children under an age of ten years (Trost, 2007). Standardized tests allow an objective evaluation of the data. However, some clinical motor test (e.g. mABC) used in the interventions only provide vague results in the context of the cerebral palsy. They have not been validated for children with cerebral palsy. The results of the assessments of Sandlund et al. (2011) revealed floor and ceiling effects in the mABD test. This indicates that the test is not sensitive enough to evaluate movement control of children with cerebral palsy. Other frequently used assessments like the Gross Motor Function Measure (GMFM), the BOTMP, and the Melbourne Assessment of Unilateral Upper Limb Functionary are validated assessments that are adequate for children with cerebral palsy (McDowell, Kerr, Parkes & Cosgrove, 2005; Randall, Ralin, Chondros & Reddihough, 2001). Better methodology with validated and reliable measurement methods would improve the strength of the evidence in this area of clinical research.

Effectiveness and limitation of evaluated outcome measures

Most of the intervention reviewed in this study present good effectiveness in enhancing physical activity and strength. Six of the 13 interventions are ´more effective`. The improvements refer to gross motor functions, muscle strength, coordination, motor performance, stability and upper extremity functions. All studies using a pre- and posttest design such as I1, I2 and I11 are more effective, indicating that the functional outcomes in children with cerebral palsy improved by means of the intervention. Moreover, three interventions are ´less effective`. This finding includes light progresses in the level of physical abilities, arm functions and balance. Only three interventions are ´ineffective`. It is outstanding that all interventions working with a control groups expose less effective or ineffective results (I6, I10 and I13). In these cases, the game exercises were not necessarily as effective as or even less effective than their standard counterparts. This gives rise to the fact, that the improvements in the experimental group cannot be attributed to the game-play. However, this small amount of ´ineffective` studies can be attributed to circumstances in the intervention set up even if the reasons are not explicitly given. For example, the game based intervention of Yong et al. (2011) was given in addition to conventional physiotherapy. This may lead to a distorted picture on the impact of the game-based therapy because the effects could also be attributed to the conventional therapy. Because of the additional therapeutic treatment to the game interventions, the improvements cannot be accredited exclusively to the intervention program. In sum, it is not confirmed that game-based therapy is better than conventional therapy, but there is evidence to state that gamification has a great potential to help children with cerebral palsy in the short term.

However, caution should be exercised in the use of these findings. The level of evidence is limited due to the small number of studies, and a lack of well-designed games with possibilities for technical adjustment and controlled research. In many cases the experimenter, who is performing the evaluation, was not blinded to the therapy protocol (I1 and I3) and constant supervision and support was needed in many studies (I1, I2, I5 and I13). This restricts a generalization of the findings. Besides, the deficits decline the reliability of the conclusions because of a low level of comparability of the studies. A very heterogeneous sample is used across the interventions and the duration of the played sessions is very variable. Additionally, it was not always ensured that the measurements of the subjects are based on the same game. Participants were free to choose their favorite games (I2, I4, I7, I8 and I11) and could decide how much time they preferred to spend at the game play (I4). These findings correspond to recent examined literature of Bonnechere, Jansen, Omelina, Degelaen, Wermenbol, Rooze and Jan (2014). They showed in their review that the studies lack standardization in rehabilitation strategies and in the use of scales and score. To avoid those problems more sufficient testing with standardization strategies to get more reliable conclusions is proposed.

The present interventions also provide additional material about motivation. It is important to mention, because it seems to be a paramount to the treatment success. The motivation is measured by game diaries or questionnaires. Across almost all of the interventions, a common finding was that children reported high levels of motivation and enjoyment (I4, I6, I11, I12 and I13). Apparently, motivation has the ability to allow children to perform actions that are otherwise difficult to achieve because of motivational issues. Only one intervention concurrently mentioned that children needed encouragement from the family to maintain the game-therapy (I2). It can be concluded that game-based therapies promote positive experience at least in the short term.

Methodological considerations

This systematic review made the thorough effort to find all relevant articles published within the database that has been created in 2013. The search strategy was based on different combinations of general key-terms of the relevant constructs. Broad search terms higher the likelihood of covering all word combinations central to the topic. Nevertheless, this cannot perfectly guarantee that important papers are not missed. The way in which the data are extracted also bares some limitations. Only this information is recovered from the articles that are prescribed by the established categories of data extraction.

Furthermore, the exploration-process demonstrates drawbacks. The study subjects constitute a very heterogeneous group and the therapy goals show large disparities, which build an obstacle for a generalization of their effectiveness. Consequently, it is difficult to elaborate the interventions in comparison with each other. General findings and evaluation should be regarded with caution because the explanatory power of the included interventions is restricted. Tools from Morrison et al. (2012) and Reeves et al. (2009) are consulted in order to reach some unity in the findings. Even if their strength is to give an objective and complete structure, they may be biased with respect to this topic. The taxonomy “Ten ingredients of Great Games” by Reeves et al. (2009), for example, is based on off-the-shelf video games and may not function for analyzing serious games. Nevertheless the outcomes of this review are consistent with the results of other reviews and studies. Therefore, it can be anticipated that the limitations still range within a tolerable scope.

Conclusion

The present evidence of these and earlier published research is poor due to a lack of well-designed studies. Gamification is a field that is at an early stage of the development characterized by successful ´proof of concept` systems with technological limitations. But even if the assessment of the effectiveness is narrowed down to studies with reliable outcome-measures in this review, the vast majority still presents positive findings. Motion games seem to be feasible for children with mild to moderate cerebral palsy. A vast majority of the studies concluded that games promote the motivation to practice and lead to an increased physical activity in both therapeutic and home-based therapy settings. This is supported by findings of the review of Parson, Rizzo, Rogers and York (2009). They found that gaming seems to be an effective rehabilitation tool for children with cerebral palsy. Nonetheless, based on the findings of this review the game-based therapy is only as effective as their standard counterparts.

In conclusion, game-based therapy is not better than conventional physical therapy, but infuse children with cerebral palsy with joy in exercise. Games have the capacity to modify uninteresting activities in a way to make them joyful and engaging. If all recommendation for further research will be taken into account, the results may even show better improvements.

Implications for further research

First of all more studies including a larger sample size with more homogeneous subject groups, like matching ages and children with same level of functionality, in order to enable generalization and comparisons of the findings are needed. It is also important to have a standardized duration of the therapy regime. It seems to be fruitful to keep up the recommendation of O´Neil et al. (2006) and set up a therapeutic program for a minimum of ten weeks with two or three sessions a week. To ensure a generalized adoption of the learned skills into the everyday life of the children with cerebral palsy, the game based therapy should be implemented in multiple settings. Portable games, which can be easily installed in other environments, such like schools or friends' homes, may facilitate the application of games at different places. Besides, it is recommended to utilize more of the different technologies that are momentarily available. Advanced technologies could be used in teaching the children motor control in a more user-centered way. The growing selection of games and devices provide the opportunity to meet specific rehabilitation goals for the individual child. To realize an appropriate game designer should consult measurements of the "flow" (Chen, 2007). "Flow" describes a mental state of energized focus, full involvement and enjoyment. It is for every child on an individual level depending on his or her ability. Children with cerebral palsy may reach they right state of flow earlier than healthy children and get quicker frustrated or bored than healthy children. Besides that an investigation of the game elements has to be taken into account. The usefulness of the “Ten ingredients of great games” for serious games is not confirmed yet. However, the elements rank, levels, explicit rules for competition and feedback appear to be important and effective. Further research should concentrate on customizing more game elements to serve the purposes of children with cerebral palsy.

Nowadays the interventions use a wide range of measures, which are directed at different outcomes of therapy and are not validated for the use by children with cerebral palsy. Standardized tools often include a limited responsiveness to change. Further research should carefully select measurement methods regarding their validity and reliability. Validation and standardization of tests may be achieved through studies of correlation between measures. It is important to be able to measure and evaluate children’s progress towards their individual therapy goals. Simplifying the data-analysis by an uncritical use of already existing questionnaires will probably lead to biased outcomes. Therefore custom-made questions are needed, which allow some reasoning about how the children with cerebral palsy utilize the customization of games. The working model for usability measures developed by Hornbæk (2006) provides a set of deliberations which should be taken into account during the data-analysis.

Until now we know little about how the motivation develops as the children with cerebral palsy spend more time interacting with the game and how trade-offs and relations between the satisfaction and effectiveness change over time. For that reason it is recommended researching on long-term effects by implementing later post-test and letting the children play over a longer period of time. This will give more credible statements regarding the usefulness of gamification in therapies for children with cerebral palsy.

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