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REVIEW ARTICLE

Serious Game-based Intervention for Children with Developmental Disabilities

Peter Kokol[1], Helena Blažun Vošner[2,3], Jernej Završnik[2], Joeri Vermeulen[4], Samaa Shohieb[5] and Frank Peinemann[6,7,*]

[1]*Faculty of Electrical Engineering and Computer Science, University of Maribor, Maribor, Slovenia;* [2]*Community Healthcare Centre Dr. Adolf Drolc, Maribor, Slovenia;* [3]*Faculty of Health and Social Sciences Slovenj Gradec, University of Maribor, Slovenj Gradec, Slovenia;* [4]*Department Health Care, Knowledge Centre Brussels Integrated Care, Erasmus University College Brussels, Brussels, Belgium;* [5]*Faculty of Computers and Information, Mansoura University, Aldaqahlia, Egypt;* [6]*Children's Hospital, University Hospital, Cologne, Germany;* [7]*FOM University of Applied Science for Economics & Management, Essen, Germany*

ARTICLE HISTORY

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Abstract: ***Background*:** Children with developmental disabilities may need support with motor skills such as balance improvement, cognitive skills such as vocabulary learning, or social skills such as adequate interpretation of emotional expressions. Digital interactive games could support the standard treatments. We aimed to review clinical studies which investigated the application of serious games in children with developmental disabilities.

***Methods*:** We searched MEDLINE and Scopus on 05 May 2019 limited to the English language. We included people between two and 24 years of age who were affected by neurodevelopmental disorders and who received digital serious game-based medical interventions such as any computer-based or video-based games. We considered any study design reporting primary data. We used title, abstract, and full-text of journal articles to build diagnostic groups, and we described some selected specific game applications.

***Results*:** The majority of the 145 relevant studies reported on autism spectrum disorder (ASD), attention deficit hyperactivity disorder (ADHD), developmental coordination disorder (DCD), and disabilities affecting intellectual abilities (DAIA). 30 of the 145 studies reported a randomized design. We detailed six specific applications aimed at improving abilities in children with ASD, ADHD, cerebral palsy, and Down syndrome. We visualized the diagnostic groups by bibliographic mapping, and limited the text to the title and abstract of journal articles.

***Conclusion*:** We identified promising results regarding anxiety reduction, stress regulation, emotion recognition, and rehabilitation. Currently, there appears to be a lack of clinical evidence that children with neurodevelopmental disorders can benefit from the application of serious games.

Keywords: Children, game-based intervention, autism spectrum disorder, attention deficit hyperactivity disorder, developmental coordination disorder, disabilities affecting intellectual abilities.

1. INTRODUCTION

A serious game has a primary purpose other than entertainment and is most prevalent as a digital game such as video games and computer games [1]. Its broad range of application domains includes complex learning for students, collaborative training for business, change of behavior, and improvement of health [2]. Examples of serious game-based use in healthcare may include improving cognitive and motor skills in rehabilitation, health promotion and education, medical education, and patient distraction during painful treatment [3]. Kagohara 2013 concluded in a systematic review on educational programs that serious games can provide technological aid with acquiring academic, communication, employment, and leisure skills in individuals with developmental disabilities [1]. Holtz 2018 concluded in a systematic review on children with chronic diseases that serious games have the potential to improve health outcomes [4]. The review included 18 randomized controlled trials, of which nine studies were associated with developmental coordination disorder. Lau 2017 concluded a systematic review on mental health that serious games may reduce symptoms [5]. The review included 10 randomized controlled trials, of

*Address correspondence to Children's Hospital, University Hospital, Kerpener Str. 62, 50937 Cologne, Germany,
E-mail: pubmedprjournal@gmail.com.

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which six studies were associated with children affected by autism spectrum disorder, attention deficit hyperactivity disorder, or depressive disorder. We aimed to review clinical studies which investigated the application of serious games in children with developmental disabilities.

2. METHODS

We searched the bibliographic databases MEDLINE *via* PubMed (U.S. National Library of Medicine) and Scopus (Elsevier). The search strategies are shown in Table **1**.

Inclusion criteria: Population: Children, adolescents, and young adults between two and 24 years of age who were diagnosed with a neurodevelopmental disorder. Intervention: Digital serious game-based medical interventions such as any computer-based or video-based games. The study design includes clinical studies reporting primary data.

Exclusion criteria: Population: People affected by impairments which may not be denoted developmental such as lower limb amputation or traumatic brain injury; video game addiction; internet addiction disorder. Intervention: Games for entertaining and related adverse events. Publication type: Secondary data relating to information originally presented elsewhere such as textbooks, reviews, commentaries, and editorials.

We imported the bibliographic data into EndNote (Clarivate Analytics). In a first screening, we excluded the records that did not meet the inclusion criteria based on title and/or abstract assessment. Records of conference proceedings, books, and series were not considered. In a second screening, we included the records of journal articles that met the inclusion criteria based on full-text assessment.

The included studies were assigned to diagnostic categories, and we used the terms of journal articles only. We added a visualization of the network of cardinal terms, which are found in the title and/or abstract and which are associated with the identified diagnoses. We used the VOSviewer version 1.6.11 and the corresponding 2019 manual to create an image showing the bibliometric mapping of the cardinal terms including their positions and interconnections within a term-based network [6, 7]. The setting to create a map including the selection of 44 terms used for the creation of the image is detailed in Table **2**. For the purpose of VOSviewer, we used the terms of journal articles only.

3. RESULTS

Of 440 retrieved records, we identified 301 records associated with journal articles (Fig. **1**). We used the terms of 145 relevant publications to build 12 diagnostic groups. The most frequently reported diagnostic groups were Autism Spectrum Disorder (ASD), Developmental Coordination Disorder (DCD), Attention Deficit Hyperactivity Disorder (ADHD), and Disabilities Affecting Intellectual Abilities (DAIA), comprising 118 of 145 records (Table **3**). Of the 145 studies, 30 were reported to have a randomized design. We used the title and abstract text to feed the VOSviewer which created similar clusters of terms associated with diagnostic groups (Fig. **2**). Based on the Scopus references, we identified six specific applications of serious games including 1) Serious games for facial expression and

Table 1. Search strategies.

Search 1	**Query (PubMed Search on 05 May 2019)**
#1	"Neurodevelopmental Disorders"[Mesh]
#2	Neurodevelopmental disorders
#3	"Disabled Persons"[Mesh]
#4	Disabled persons
#5	"Intellectual Disability"[Mesh]
#6	Intellectual disability
#7	"Child"[Mesh]
#8	Children
#9	"Adolescent"[Mesh]
#10	Adolescents
#11	"Young Adult"[Mesh]
#12	Young adults
#13	"Video Games"[Mesh]
#14	Game-based
#15	Computer-based game or computer-based games
#16	Video-based game or video-based games
#17	Application-based game or application-based games
#18	App-based game or app-based games
#19	Mobile game or mobile games
#20	Software-based game or software-based games
#21	Serious game or serious games
#22	#1 or #2 or #3 or #4 or #5 or #6
#23	#7 or #8 or #9 or #10 or #11 or #12
#24	#13 or #14 or #15 or #16 or #17 #18 or #19 or #20 or #21
#25	#22 and #23 and #24
Search 2	**Query (Scopus search on 05 May 2019)**
#1	Autism
#2	Down
#3	Cerebral
#4	Neuro-developmental
#5	Mental
#6	ADHD
#7	"Intellectual disability"
#8	Children
#9	Adolescent
#10	"Serious games"
#11	#1 or #2 or #3 or #4 or #5 or #6 or #7
#12	#8 or #9
#13	#10 and #11 and #12

Table 2. VOSviewer steps.

Step	Task	Description
#1	Tabs "network visualization", "file", and "map"	Create
#2	Choose type of data	Create a map based on text data (to create a term co-occurrence map based on text data)
#3	Choose data source	Read data from reference manager files (supported file types RIS, EndNote, and RefWorks)
#4	Select files	EndNote; Import EndNote format file (.txt): 145 references of 301 journal articles identified through PubMed.
#5	Choose fields	(from which terms will be extracted) Title and abstract fields.
#6	-	System extracts terms
#7	Choose counting method	Binary counting
#8	Choose threshold	Minimum number of occurrences of a term: We chose 5 times. Of the 3727 terms, 195 meet the threshold.
#9	Choose number of terms	For each of the 162 terms, a relevance score will be calculated. Based on this score, the most relevant terms will be selected. The default choice is to select the 60% most relevant terms. The system selected 117 terms and calculated the relevance scores.
#10	Verify selected terms	Of the 117 optional terms, we selected 35 terms associated with developmental disabilities or electronic games: action video games; adhd; application; asd; attention deficit hyperactivity disorder; autism; autism spectrum disorder; behavior; cerebral palsy; dcd; deficit hyperactivity disorder; developmental disability; developmental coordination disorder; disability; dyslexic child; dyslexia; emotion; emotion recognition; engagement; face; impairment; intellectual disability; interaction; memory; mental health; motivation; perception; physical activity; relationship; rehabilitation; serious games; speech; social interaction; virtual reality; wii; Of the 117 optional terms, we did not select 82 terms not specifically associated with developmental disabilities: accuracy; acquisition; addition; adolescent; adult; article; avg; balance; baseline; benefit; body; boy; comparison; component; context; criterium; current study; daily life; data; deficit; diagnosis; duration; efficiency; end; enjoyment; evaluation; exercise; experiment; experimental group; female; frequency; future research; girl; greater improvement; hand; impact; implication; individual; interest; intervention group; intervention phase; learning; limitation; male; min; minute; motor proficiency; movement assessment battery; order; paper; person; period; population; pre; present study; primary outcome; question; report; research; secondary outcome; set; significant improvement; speed; student; subject; symptom; system; target response; teacher; technology; term; tool; transfer; trial registration; typical development; usability; user; way; week period; work; young child; youth.
#11	Finish	System creates the bibliographic term mapping image.

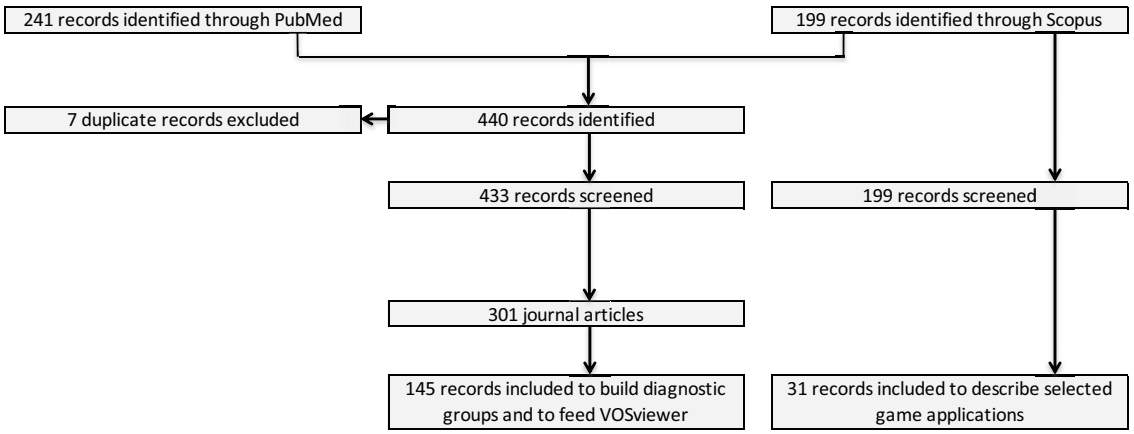

Fig. (1). Literature retrieval and record flow.

Table 3. Diagnosis groups.

Diagnosis Group	Articles	RCT
Autism spectrum disorder (ASD)	45	6
Developmental coordination disorder (DCD)	26	7
Attention deficit hyperactivity disorder (ADHD)	24	9
Disabilities affecting intellectual abilities	23	4
Dyslexia	9	0
Cerebral palsy	7	1
Down syndrome	3	0
Hearing impairment	2	0
Visual impairment	2	0
Fetal alcohol spectrum	2	2
Multiple sclerosis	1	1
Mutism	1	0
Total	**145**	**30**

Caption: RCT: Randomized Controlled Trial.

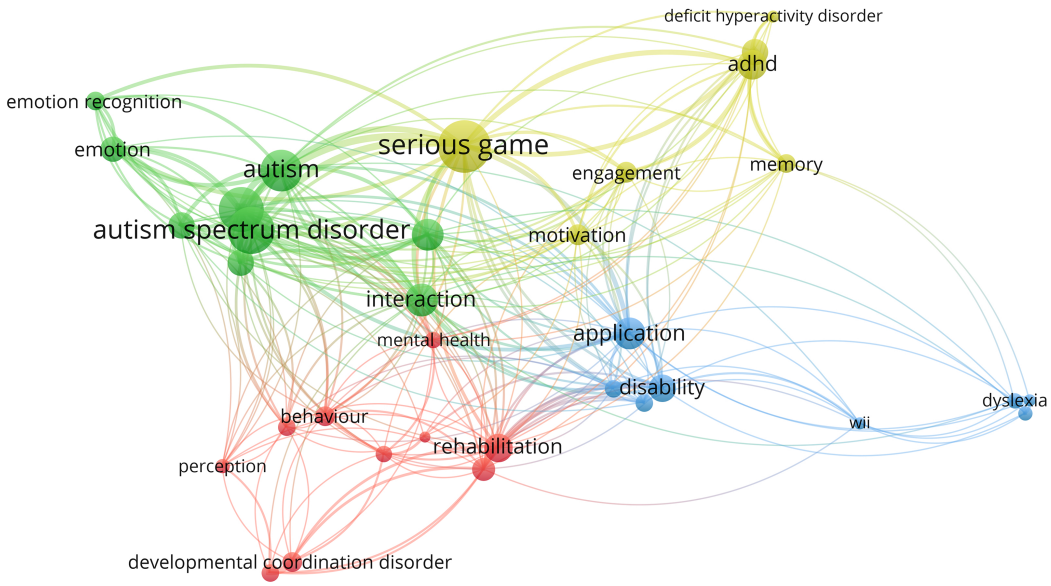

Fig. (2). Bibliographic mapping using VOSviewer. Terms retrieved from the title and abstract of 145 journal articles reporting on children and young adults with neurodevelopmental disorders who received digital serious game-based medical interventions. Color visualizes a network of terms associated with diagnostic groups.

emotions recognition in children with ASD, 2) Serious games for education of children with ASD, 3) Mobile devices for children with ASD, 4) Serious games for children with ADHD, 5) Serious games for children with cerebral palsy, and 6 Serious Games for children with Down Syndrome.

4. DISCUSSION

4.1. Serious Games for Facial Expression and Emotions Recognition in Children with ASD

Authors encountered that most applications are limited and not clinically proven by randomized controlled trials. However, they still advise the use of games to teach children with ASD to recognize facial expressions and emotions. In that context, the game called *JeStiMulE*, a computer-based game aiming to teach emotions, showed promising results in teaching emotion recognition to children with low functioning autism [8]. Some other games like *LIFEisGAME* [9], *Emotioplay* [10], and *CopyMe* [11] were reported to improve emotion recognition also enhanced body language or eye gaze recognition and adaptive socialization [12]. Additionally, the serious game called *JEMImE* teaches children with ASD how to produce facial expressions. Children have to perform facial expressions on request or based on social

situations [13]. Teaching and practicing social interactions is the objective of the serious game *ECHOES*. Simulated activities take place in a so-called sensory garden. Activities are supported by a virtual agent who acts as best practice skilled social partner. Preliminary experiments showed encouraging results [14]. Mindlight is a serious game aiming to decrease anxiety in children with ASD, using evidence-based therapeutic practices. A recent study showed a significant reduction in anxiety symptoms and state anxiety in response to stress [15]. An interesting approach in designing serious games for children with ASD is the participatory design showing positive effects in children with ASD in both the development of the games as well as when playing [16]. An even more advanced approach is to use human-robot interaction to teach children with ASD how to recognize emotions [17].

4.2. Serious Games for the Education of Children with ASD

JeStiMulE [8] showed its possible usability also in an educational context in terms of adaptability, effectiveness and efficiency. The experiment showed that children were significantly better in recognizing emotions after using the game especially in recognizing sadness, happiness and anger. *GOLIAH* [18] is a nomadically deployable closed-loop intervention system involving children with ASD, their parents and therapists. The system consists of eleven highly flexibly games incorporating visual and audio stimuli. *GOLIAH* was evaluated in a 3-month open trial including children with autism and their parents in both hospital and home environment. The trial highlighted enhancement in the child's concentration and flexibility in more than three quarter of children and improvement of self-esteem in almost half of the children. A serious game incorporating virtual reality where children play and interact with pink dolphins showed positive effects on psychomotor skills and hand eye co-ordination in children with ASD. Husni 2013 [19] designed and implemented a vocabulary learning application for children with autism on Android based mobile devices. Also, Constantin 2017 [20] presented two study participatory design research related games to children with ASD and intellectual disabilities. The study applied two research questions related to 1) The reward possibilities of children with ASD and/or intellectual disabilities and 2) Possibilities of children's development and progress throughout an assignment and rewards. Belmonte *et al.* 2016 [21] designed a tablet-based software in collaboration with autistic clients and their communication therapists, to motivate attention to learning manual motor and oral motor skills essential for communication. Aziz *et al.* 2014 [22] developed an application that helps children with ASD to enhance their social life in communicating and interacting with others whilst supporting their caregivers and parents to recognize what the children honestly desires. The concerning application can be customized (*i.e.* to include more activities) as the needs might arise. Mendonça *et al.* 2015 [23] designed a platform for children with ASD to develop generalization skills and language. That application helps caregivers to construct custom-designed exercises with multiple choice which considers the unique characteristics of every child. Kamaruzaman *et al.* 2013 [24] proposed several prototypes of game-based learning to educate low functioning autism (LFA) and selected the best model to be applied in prototypes design. They tested their model on 15 LFA children, aged between 5 and 10 years old had been conducted to evaluate the efficiency of the game in assisting in learning the holy Quran.

4.3. Mobile Devices for Children with ASD

The fast development of information and communication technology enabled the development of automatic applications for emotion recognition on mobile and personal devices [25]. The serious mobile game *GameBook* [26] assists children with ASD to recognize and acquire emotions by promoting the interaction between the child and a story teller, a three-dimensional avatar. *GOLIAH* [18] system is also implemented as a mobile serious gaming platform. The mobile application *Leon con Lula* ("reading with Lula", in Spanish) uses global reading methods to promote reading skills of children with ASD [27].

4.4. Serious Games for Children with ADHD

ChillFish is a respiration game that can help children with ADHD to control their stress level with breathing exercises, based on controlled biofeedback. A pilot study showed a positive effect of the game in reaching a relaxed state [28]. To overcome the limitations of available games for children with ADHD, like lack of ability to demonstrate the generalization of game based acquired skills to daily life situations. A new serious game called *Plan-It Commander* was developed for these children to develop essential life skills. The game has a strong theoretical background based on psychological principles from the Self-Regulation Model, Social Cognitive Theory, and Learning Theory. A multisite randomized controlled crossover open-label trial showed that after 10 weeks, participants using *Plan-It-Commander* as an adjunct to conventional therapy achieved significantly greater improvements in time management skills, social responsibility and working memory, than the control group [29]. Recently, augmented reality has been used to train children to improve their attention span using natural user interfaces provide by *Kinect* [30]. It has been demonstrated that the use of their augmented reality serious game improved the attention and retention and frustration tolerance in children with ADHD. Interestingly, a study on 26 girls and 47 boys aiming to identify the benefits of serious games in ADHD children, revealed that girls are more likely to improve deficit hyperactivity symptoms than boys [31].

4.5. Serious Games for Children with Cerebral Palsy

A review of 31 papers on the use of serious games in conjunction with conventional treatment of children with cerebral palsy, showed that it is difficult to compare studies objectively, due to the lack of standardization and use of various clinical measurements [32]. Consequently, there is not enough evidence to show the positive effects of serious games to cerebral palsy treatment in children. On the other hand, it has been documented that serious games improve the balance of cerebral palsy children [33] support rehabilitation exercises to enhance the management of facial muscles, swallowing process, and speech [34], as well as cervical and trunk control [10].

4.6. Serious Games for Children with Down Syndrome

Rahman 2010 [35] conducted a program of three *Wii-Fit* games for Down syndrome (DS) study group in addition to the traditional physical therapy program. The results revealed significant improvement of balance in the study group ($p < 0.001$) when compared with that of the control group who received the traditional physical therapy program. This result indicated that *Wii-Fit* games as a virtual reality-based therapy could improve balance for children with DS. Another study including a 12-year-old child with a diagnosis of DS and with limited *Wii* exposure was asked to play *Wii* games in the home 4 times each week for 20 minutes each session for 8 weeks. Family members were encouraged to participate. The participant chose what games to play and selected 4 different games. Repeatedly practicing the skills involved in these games resulted in improvements in the child's postural stability, limits of stability, and Bruininks-Oseretsky Test of Motor Proficiency, 2nd edition balance, upper-limb coordination, manual dexterity, and running speed and agility standard scores. A study showed that Wii game use by children with DS may elicit improvements in highly practiced motor skills and postural control [36]. Brandão *et al.* 2014 [37] developed a game called *JECRIPE* aimed for children with DS in pre-scholar age. The major purpose of that game was to promote cognitive development of disabled children in the context of inclusive education. In order to do so, the game addresses aspects of interaction, communication and game design in stimulating selected cognitive abilities. Based on the evidence that adolescents with DA consume fewer calories, vitamins and trace elements than prescribed by Recommended Daily Intake, Hatzigiannakoglou 2015 [38] developed a serious game, played either with a *Wii-Remote* (Nintendo remote controller) or a mouse, which helps adolescents with DS, to adopt their diet to a more balanced nutrition.

CONCLUSION

Studies on the use of serious games in children with neurodevelopmental disorders appeared to be used principally in children with autism spectrum disorder, attention deficit hyperactivity disorder, developmental coordination disorder, and disabilities affecting intellectual abilities. Most studies are not randomized. There are promising results regarding the potential reduction of anxiety, stress regulation, and emotion recognition in children with neurodevelopmental disorders. There are also positive findings regarding the rehabilitation of children with cerebral palsy. Nevertheless, there appears to be a lack of clinical evidence that children with neurodevelopmental disorders can benefit from the application of serious games.

LIST OF ABBREVIATIONS

ADHD	=	Attention Deficit Hyperactivity Disorder
ASD	=	Autism Spectrum Disorder
DAIA	=	Disabilities Affecting Intellectual Abilities
DCD	=	Developmental Coordination Disorder
DS	=	Down Syndrome

CONSENT FOR PUBLICATION

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CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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