An Overview of Virtual Reality Interventions for Two Neurodevelopmental Disorders: Intellectual Disabilities and Autism

Anders Nordahl-Hansen[1(✉)], Anders Dechsling[1], Stefan Sütterlin[1,2], Line Børtveit[1], Dajie Zhang[3,4,5], Roald A. Øien[6,7], and Peter B. Marschik[3,4,5,8]

[1] Østfold University College, Halden, Norway
{anders.nordahl-hansen,anders.dechsling, stefan.sutterlin}@hiof.no, linebortveit@gmail.com
[2] Division of Clinical Neuroscience, Oslo University Hospital, Oslo, Norway
[3] Child and Adolescent Psychiatry and Psychotherapy, University Medical Center, Göttingen, Germany
{Dajie.marschik,peter.marschik}@med.uni-goettingen.de
[4] Leibniz Science Primate Cognition, Göttingen, Germany
[5] Division of Phoniatrics, Medical University of Graz, Graz, Austria
[6] School of Medicine, Yale University, Child Study Center, New Haven, USA
roald.a.oien@uit.no
[7] The Arctic University of—University of Tromsø, Tromsø, Norway
[8] Center of Neurodevelopmental Disorders, Department of Women's and Children's Health, Karolinska Institutet, Stockholm, Sweden

Abstract. In this overview of the two neurodevelopmental disorders, intellectual disabilities and autism spectrum disorders we systematically searched the literature for scientific publications of group-based designs that tested various interventions through the use of Virtual Reality technology. After screening of a total of n = 366 publications, n = 13 studies (intellectual disabilities n = 7, autism spectrum disorders n = 6) were included in the final analyses. We present descriptive data in terms of type of intervention content for the various studies as well as information regarding research design, number of participants enrolled in the studies, age cohorts, and outcome measures. We discuss the findings as a whole but also by comparing the studies that are published within each of the two neurodevelopmental disorder groups. Finally we discuss some challenges and opportunities for future research.

Keywords: Autism Spectrum Disorder · Intellectual disabilities · Virtual Reality · Measurement · Intervention

1 Introduction

Virtual Reality (VR) is defined as 'artificial environment which is experienced through sensory stimuli (such as sights and sounds) provided by a computer and in which one's actions partially determine what happens in the environment' [1].

D. D. Schmorrow and C. M. Fidopiastis (Eds.): HCII 2020, LNAI 12197, pp. 257–267, 2020.
https://doi.org/10.1007/978-3-030-50439-7_17

VR has not only become popular for the gaming industry but has been continuously developed to implement educational and interventional approaches, with a strong focus on certain psychiatric disorders. VR interventions for individuals with psychiatric diagnoses and its effectiveness have repeatedly been reported for diagnostic groups such as anxiety and depression [2]. VR interventions allow for controllable and safe exposure that are difficult to construct in real world settings.

Typical intervention settings for children and adolescents with neurodevelopmental disorders such as autism spectrum disorder (ASD) and intellectual disability (ID), are one-to-one training sessions. Target of these interventions for neurodevelopmental groups vary but usually include specified training within areas of language, non-verbal communication and social skills, learning of specific academic skills as well as daily living skills. All these areas of training can be supported by using VR technology [3]. Common outcome measures assessed in VR-supported therapeutic interventions include behavioral and emotional functioning levels, typically obtained via observation, questionnaires, or parental reports. Although there is no shortage of available measures [4], no consensus exists regarding which measures should be used to appraise therapeutic success [5]. For a first discussion and overview of intervention research within neurodevelopmental disorders we chose to focus on autism spectrum disorders (ASD) and intellectual disability (ID) as two major conditions of interest to be studied in VR research (Table 1).

Table 1. Diagnostic criteria for ASD and ID from DSM-5 [6]. *IQ may not always be an exact feature, has to be seen in relation to the qualitative indications of the other functions.

Autism Spectrum Disorders (ASD)	Intellectual Disability (ID)
Deficits in communication and social interaction	Deficits in intellectual functions
Repetitive patterns in behaviour and activities	Deficits in adaptive functions compared to developmental standards
No criteria regarding IQ, however, the IQ may indicate level of severity	Onset of the above mentioned deficits during the developmental period
	IQ>70*

VR systems are not yet widely used in clinical interventions and when VR is being used in clinical studies it is rather an implementation of an already existing therapeutic concept. Further, significant outcomes are not always expected [7] as most interventions are short-term pilot-studies. Also, most behavioral intervention studies for individuals with neurodevelopmental disorders indicate that although there might be an effect of the intervention at short-term follow-ups, this effect tends to fade out when longer term follow-ups are carried out [8].

In their review of the 31 published articles on VR in children and adolescents with ASD, Mesa-Gresa and colleagues [7] mentioned over 25 different standardized evaluation forms, and an additional 46 specifically constructed/newly designed evaluation forms of effectiveness and outcome measures. The findings extracted from Mesa-Gresa et al. illustrate the lack of consensus in regard of the use of common outcome measures. As noted earlier, this is however not only a problem within VR-research and ASD but the intervention research in general. In this study we conduct a systematic search for empirical intervention studies that used VR technology in children and adolescents with neurodevelopmental disorders. We investigated what type of designs, intervention types, sample size, age cohorts and outcome measures that have been used in intervention trials using group-based research designs for individuals with ASD and ID. Our intentions for conducting this review is to get an overview of intervention studies within two of the most common neurodevelopmental disorder groups. We address implications for future research using VR in interventions studies with individuals with neurodevelopmental disorders.

2 Method

2.1 Literature Search

We systematically searched for empirical VR-based intervention studies. The literature search was conducted in the second week of January 2020. We searched the databases PubMed, PsycINFO, and ERIC that are broad-based but with a focus on articles related to medicine, health, psychology, and education. The search string below with Boolean operators was used to search titles and abstracts: autism OR autistic OR asd OR asperger* OR pervasive development* disorder* OR pdd OR pdd-nos AND virtual reality OR vr OR virtual world OR cyberspace OR hmd OR head-mounted display* OR virtual learning environment OR immersive virtual environment OR augmented reality OR artificial reality OR oculus OR display technolog* OR immersive technolog* OR mixed reality OR hybrid reality OR virtual environment OR immersive virtual reality system OR 3d environment OR htc vive OR cave OR virtual reality exposure AND intervent* OR treat* OR therap* OR train* AND experiment OR randomized controlled trial OR randomised controlled trial OR controlled clinical trial OR group* OR quasi experiment. We used the same search string only substituting the first part related to autism diagnosis with: intellectual impairment OR intellectual disability* OR intellectual dysfunction OR developmental disabilit* OR intellectual developmental disorder OR mental deficiency OR mental* retard* OR mental* handicap* OR mental* disab* OR mental* insufficiency OR mental impair* OR mental* subnormality OR learning disabilit*. In addition to the structured search, we conducted an ancestry search of all authors of relevant papers. A search string like this enabled us to compare empirical evidence across the autism spectrum diagnosis and intellectual disability.

2.2 Inclusion Criteria

Following the literature search relevant articles on VR and therapeutical interventions were selected based on the following inclusion criteria: publications had to include therapeutic interventions with human participants with a diagnosis of ASD or intellectual disability (if participants had syndromic variations such as Down Syndrome but were categorized and met general criteria for an ID diagnosis, these studies were also included); studies had to be in English language and published in peer-reviewed journals; we included group comparison studies, with participants assigned to at least two groups (case-control designs).

2.3 Screening and Study Selection

The total number of studies from the initial search was N = 366. We removed all duplicates and one of the authors (LB) screened the remaining titles and abstracts. Another author (AN-H) double-screened 45 titles and abstracts (approx. 15%) of the titles and abstracts for reliability purposes. Agreement was met on 43 of the 45 abstracts and the two publications where there was disagreement were included for closer full-text inspection. Full-texts were assessed for eligibility by two authors (AN-H and AD). After full-text screening 13 (ASD n = 6, ID n = 7) publications were included in the final review and included in Tables 2 and 3. The screening process is depicted in Fig. 1.

2.4 Criteria for Included Participant Numbers

The number of participants that were included in the final analyses are reported separately for the respective studies. We report the number of participants in the intervention after dropouts were excluded. This leads to reporting the true size of the study sample on which results are based.

2.5 Analysis

In this article we report descriptive results of the included studies. For each of the studies reported we list study design, number of participants, type of intervention, age range of participants, as well as outcome measures used. We compare the studies conducted for the two different disorders with each other to indicate trends within the intervention research.

3 Results

Details of the included studies are reported in Tables 2 and 3 below. A total of six intervention studies for persons with ASD and seven studies for persons with ID were included for final analyses (Fig. 1). The prevailing study design was of pretest-posttest structure with non-randomized groups, with small sample sizes (range 8–105 meaning smallest to largest N in ASD and ID and overall). The total number of participants in all ID-studies were n = 502, whereas for the ASD-studies the total number of participants were n = 182. The age range in ID-studies was 7–60 years, and 2–60 years in ASD-studies. Only one out of seven ID-studies, and half of the ASD-studies (3/3) were randomized controlled trials. We found a broad spectrum in terms of scope in the included research work. In most of the applications, the intervention target aimed to alter a specific well-defined behaviors, such as physical fitness, motor-skills or particular skills such as job interview training or space navigation. The typical measures of outcome for the majority of these studies were measures that can be considered proximal to the intervention target, meaning that there is a great overlap of the intervention content and the operational definition of outcome. Three of the ASD-studies [24, 25, 27] were considered broader than the remaining ones, as the intervention type and content addressed social communication in general and as such per definition targeted a core symptom and diagnostic criterion of the disorder. The outcome measures used in the three studies were also more general as the measures used are designed to capture a more global, as opposed to specifically defined skill set within social communicative behaviors.

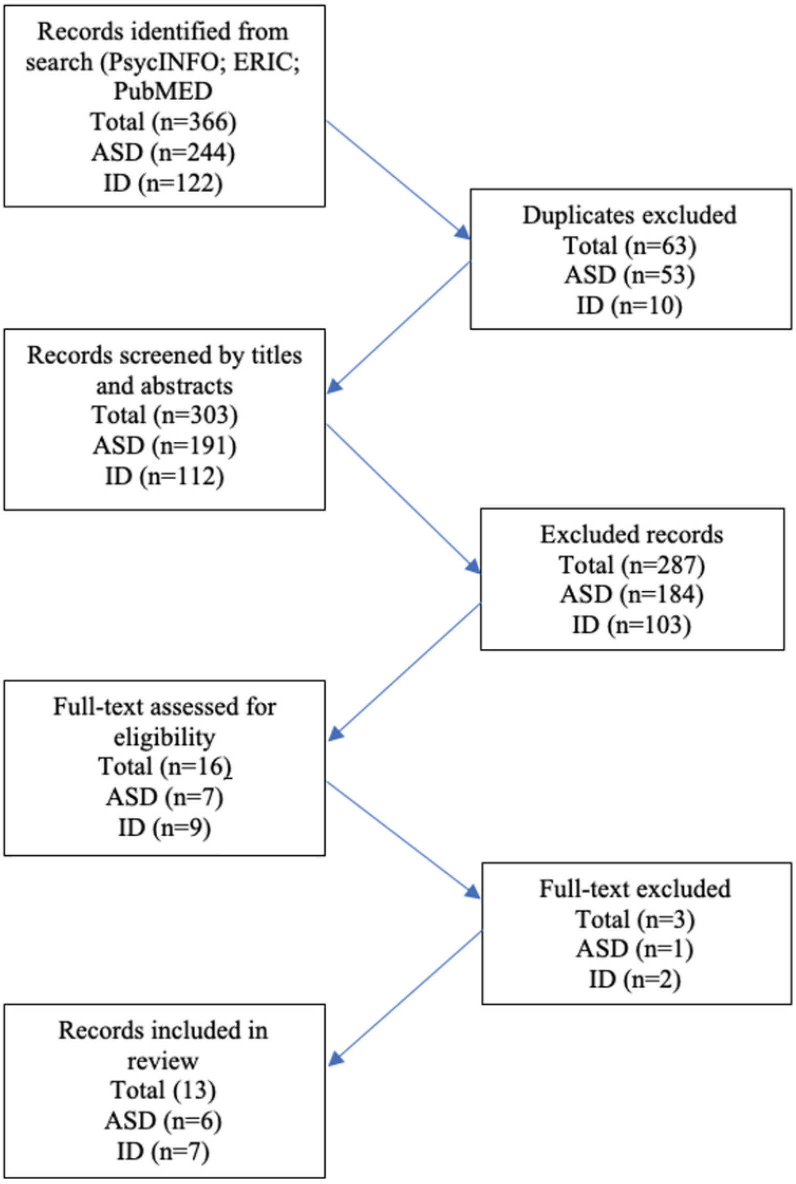

Fig. 1. Flowchart of the screening process.

Table 2. Included studies with participants with intellectual disabilities

Author (Year)	Design	Intervention type	Diagnostic label(s)	Intervention/control	Age cohort (years)	Outcome measure(s)
Lin et al. [15]	RCT	Physical exercise training	Down syndrome, intellectual disability	46/46	10.9 (mean)	Muscle strength, agility performance
Lotan et al. [16]	Pre-post-test w. two groups	Physical exercise training	Intellectual developmental disorder	30/30	35–60	Heart rate, energy expenditure index, modified Cooper test
Mengue-Topio et al. [17]	Learning phase -Post-test w. two groups	Space navigation virtual environment	intellectual disability Non-ID controls	18/18	29.39 (mean)	Mean walked distance between two points and number of attempts need to navigate correctly
Rose et al. [18]	Learning phase-post-test w. three groups	Fine motor skills (steadiness tester)	Learning disabilities	n=45 in three groups (no info on group size)	16–46	Errors during steadiness tester device
Tam et al. [20]	Pre-post-test quasi experiment w. two groups	Psychoeducational supermarket-shopping training	Intellectual disability	8/8	17–23	Checklist for supermarket shopping skills
Wuang et al. [21]	Pre-post-test quasi experiment w. two groups	Sensori-motor skills	Down syndrome	52/53	07-Dec	Motor proficiency, visual motor integration, sensory integration

Table 3. Included studies with participants with intellectual disabilities with Autism Spectrum Disorder

Author (Year)	Design	Intervention type	Diagnostic label(s)	Intervention/control	Age cohort (years)	Outcome measure(s)
Humm et al. [22]	RCT	Job interview training	ASD, Schizophrenia, PTSD	32/64	20–60	Role play interview scores
Josman et al. [23]	SSD & group comparison	Pedestrian training	ASD, typical development	6/6	8–16	Controlling an avatar in traffic
Lorenzo et al. [24]	Pre-post quasi experimental	Social interaction	ASD	5/6	2–6	Autism spectrum inventory, augmented reality social interaction score
Maskey et al. [25]	RCT	Cognitive behaviour and phobia treatment	ASD	17/16	8–14	Behavioural rating, social communication questionnaire, anxiety disorders interview schedule
Self et al. [26]	Pre-post-test w. two groups	Fire and tornado safety skills training	ASD	4/4	6–12	Que response (Yes/no)
Strickland et al. [27]	RCT	Job interview training	ASD	11/11	16–19	Interview skills rating, response delivery scale, social responsiveness scale

4 Discussion

Even though there has been a substantial increase in the use of VR in studies with neurodevelopmental disorders (e.g. Autism; [9]). Empirical evidence to support the efficacy of its implementation is however still scarce and unsystematic. Only one out of seven ID-studies and half of the ASD-studies were randomized controlled trials, which also results in the need to interpret all findings on a cautionary note. Future research with greater sample sizes will shed light on details regarding this new approach, to date the total number of participants in all ID-studies were n = 502, whereas for the ASD-studies the total number of participants were n = 182. In addition, to the age range of VR application studies ranges from 2–60 years (ID-studies: 7–60 years; ASD-studies: 2–60 years).

There was a large difference of participants enrolled in the ID-studies (n = 502) compared to ASD-studies (n = 182). A closer inspection of the age ranges in the studies also shows that, to a large extent, the studies were conducted with older children, adolescents and young adults. It is perhaps natural that the youngest children are under-represented, especially since head-mounted wearables can be difficult to use for a long time for this group. Still, Lorenzo et al. [24] did include participants as young as 2 years of age. Thus, augmented and virtual reality studies are also possible to conduct with very young children.

Using VR-devices for persons with neurodevelopmental disorders such as ASD and ID is not necessarily straight forward or easily applicable. For instance, head mounted displays can be difficult to use if the participant is reluctant or feel anxious. There can be many reasons for this, such as feelings of unease of wearing such equipment. For instance, different age-groups might react differently. In particular, as noted, with young children it can be challenging to use VR-equipment. Individuals with neurodevelopmental disorders can also experience unease such as sensory issues. However, there are individual differences in terms of the acceptability for use among this group. In fact, as is reported elsewhere in this volume [9] many studies report that acceptability of use of VR-technology is high for groups with neurodevelopmental disorders such as ASD.

Few of the included studies had older adults as participants. This age cohort are generally under-researched within the neurodevelopmental field [10], and hence in need of more focus from researchers whether conducting VR-studies or not. It is also worth noting that, in particular within the ID-studies, the studies are quite old and mainly conducted in the 2000s. For the ASD-studies, there were also some older studies but newer studies such as Lorenzo et al. and Maskey et al. indicate that interventions that in one way or another use augmented reality and virtual reality studies and different studies are in the pipeline.

4.1 Intervention Type and Outcome Measures

Assessing the studies reported here some trends emerge regarding intervention type and outcome measures deployed in the studies. All publications with ID-participants included interventions that targeted a well-defined specific skill or behavior. The measures used to assess the outcome from these studies were proximal to the intervention target, meaning that the outcome measure used highly resembles what was being trained in the intervention (e.g. fine-motor skill task as measure of outcome in an intervention targeting fine-motor skills). Specifically defined skills as intervention targets and overlapping measures of outcome were also used in the studies conducted by Humm et al., Josman et al., and Self et al. in the included ASD-studies. Such studies have high value as they go on to show that training particular skills can be taught and many of these skills can be lifesaving on its own, as well as many of the studies give clear indices that using VR for training skills can be used effectively. The studies of Lorenzo et al., Maskey et al., and Strickland et al. are somewhat different as the outcome measure are more distally, as opposed to proximal, to the intervention target [11]. Further, a dimension is added in that these studies aim to increase social communicative abilities more broadly and as such alter core diagnostic symptoms more globally [12].

5 Future Considerations

There is a need for more intervention studies using VR-technology as the body of research to date is too small. Most of the studies reported in this review have small sample sizes. Also, the studies go over a short time span and there is a particular need for studies that investigate longer terms effects following intervention. Further, the development of measures that capitalize on VR technology can potentially be used for objective outcome assessments and may compensate observational measures or parent reports. For instance, in head mounted displays used in VR-interventions it is possible to develop and capitalize on measures such as eye-tracking through the built-in technology which records for instance eye-gaze "live" during intervention [13]. However, little attention has been given to investigate the strengths and weaknesses of such assessments, nor to their potential in intervention research for children and adolescents with neurodevelopmental disorders.

6 Conclusion

Although there are some intervention studies published using VR-technology for individuals with ASD and ID, and that there are some promising results it is still difficult to conclude on the efficacy and effectiveness of such interventions. This is not surprising given the relatively short time span that VR-technology has been available for use in interventions.

Technological advancements are moving fast and opportunities for non-traditional measures are being developed. These advancements can lead to more precise outcome measures with potential clinical relevance available. However, creating a need for more systematic research on their respective validity, reliability and practical-clinical appropriateness. This may lead to better precision in terms of lower measurement error as for instance eye-tracking devices [14] and similar measures do not rely on arbitrariness in terms of subjectivity such as can be the case when observers score behavioral acts in observational scoring paradigms. This may in turn pave the way for more solid conclusions regarding the relevance and sustainability of effects following VR interventions in individuals with neurodevelopmental disorders.

References

1. The Merriam-Webster.com Dictionary. https://www.merriam-webster.com/dictionary/augmented%20reality. Accessed 29 Jan 2020
2. Fodor, L.A., Coteț, C.D., Cuijpers, P., Szamoskozi, Ș., David, D., Cristea, I.A.: The effectiveness of virtual reality based interventions for symptoms of anxiety and depression: a meta-analysis. Sci. Rep. **8**(1), 1–13 (2018)
3. Parsons, S.: Authenticity in virtual reality for assessment and intervention in autism: a conceptual review. Educ. Res. Rev. **19**, 138–157 (2016)
4. Bolte, E.E., Diehl, J.J.: Measurement tools and target symptoms/skills used to assess treatment response for individuals with autism spectrum disorder. J. Autism Dev. Disord. **43**(11), 2491–2501 (2013)
5. Nordahl-Hansen, A., Hart, L., Øien, R.A.: The scientific study of parents and caregivers of children with ASD: a flourishing field but still work to be done. https://doi.org/10.1007/s10803-018-3526-9
6. American Psychiatric Association: Diagnostic and Statistical Manual of Mental Disorders: DSM-5, 5th edn. American Psychiatric Association, Washington (2013)
7. Mesa-Gresa, P., Gil-Gómez, H., Lozano-Quilis, J., Gil-Gómez, J.A.: Effectiveness of virtual reality for children and adolescents with autism spectrum disorder: an evidence-based systematic review. Sensors **18**, 2486 (2018). https://doi.org/10.3390/s18082486
8. Bailey, D., Duncan, G.J., Odgers, C.L., Yu, W.: Persistence and fadeout in the impacts of child and adolescent interventions. J. Res. Educ. Effectiveness **10**(1), 7–39 (2017)
9. Dechsling, A., Sütterlin, S., Nordahl-Hansen, A.: Acceptability and normative considerations in research on autism spectrum disorders and virtual reality. In: Lecture Notes in Computer Science (LNCS) (2020). ISSN 0302-9743
10. Howlin, P., et al.: Research on adults with autism spectrum disorder: roundtable report. J. Intellec. Dev. Disabil. **40**(4), 388–393 (2015)
11. Yoder, P.J., Bottema-Beutel, K., Woynaroski, T., Chandrasekhar, R., Sandbank, M.: Social communication intervention effects vary by dependent variable type in preschoolers with autism spectrum disorders. Evid.-Based Commun. Assess. Interv. **7**(4), 150–174 (2013)
12. Nordahl-Hansen, A., Fletcher-Watson, S., McConachie, H., Kaale, A.: Relations between specific and global outcome measures in a social-communication intervention for children with autism spectrum disorder. Res. Autism Spectrum Disord. **29**, 19–29 (2016). https://doi.org/10.1016/j.rasd.2016.05.005
13. Lutz, O.H.M., Burmeister, C., dos Santos, L.F., Morkisch, N., Dohle, C., Krüger, J.: Application of head-mounted devices with eye-tracking in virtual reality therapy. Curr. Direc. Biomed. Eng. **3**(1), 53–56 (2017)
14. Townend, G.S., Marschik, P.B., Smeets, E., van de Berg, R., van den Berg, M., Curfs, L.M.: Eye gaze technology as a form of augmentative and alternative communication for individuals with Rett syndrome: experiences of families in The Netherlands. J. Dev. Phys. Disabil. **28**(1), 101–112 (2016)

*Studies included in systematic review alphabetically and marked with an asterisk**

15. *Lin, H.-C., Wuang, Y.-P.: Strength and agility training in adolescents with down syndrome: a randomized controlled trial. Res. Dev. Disabil. Multidisc. J. **33**(6), 2236–2244 (2012). http://dx.doi.org/10.1016/j.ridd.2012.06.017

16. *Lotan, M., Yalon-Chamovitz, S., Weiss, P.L.: Improving physical fitness of individuals with intellectual and developmental disability through a virtual reality intervention program. Res. Dev. Disabil. **30**(2), 229–239 (2009). https://doi.org/10.1016/j.ridd.2008.03.005
17. *Mengue-Topio, H., Courbois, Y., Farran, E.K., Sockeel, P.: Route learning and shortcut performance in adults with intellectual disability: a study with virtual environments. Res. Dev. Disabil. Multidisc. J. **32**(1), 345–352 (2011). http://dx.doi.org/10.1016/j.ridd.2010.10.014
18. *Rose, F., Brooks, B., Attree, E.: An exploratory investigation into the usability and usefulness of training people with learning disabilities in a virtual environment. Disabil. Rehabil. Int. Multidisc. J. **24**(11–12), 627–633 (2002). https://doi.org/10.1080/09638280110111405
19. *Passig, D.: Improving the sequential time perception of teenagers with mild to moderate mental retardation with 3D immersive virtual reality (IVR). J. Educ. Comput. Res. **40**(3), 263–280 (2009). https://doi.org/10.2190/EC.40.3.a
20. *Tam, S.-F., Man, D.W.-K., Chan, Y.-P., Sze, P.-C., Wong, C.-M.: Evaluation of a computer-assisted, 2-D virtual reality system for training people with intellectual disabilities on how to shop. Rehabil. Psychol. **50**(3), 285–291 (2005). https://doi.org/10.1037/0090-5550.50.3.285
21. *Wuang, Y.-P., Chiang, C.-S., Su, C.-Y., Wang, C.-C.: Effectiveness of virtual reality using Wii gaming technology in children with down syndrome. Res. Dev. Disabil. Multidisc. J. **32**(1), 312–321 (2011). http://dx.doi.org/10.1016/j.ridd.2010.10.002
22. *Humm, L.B., Olsen, D., Be, M., Fleming, M., Smith, M.: Simulated job interview improves skills for adults with serious mental illnesses. Annu. Rev. CyberTherapy Telemed. **12**, 50–54 (2014). http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=psyc11&AN=2015-00374-009
23. *Josman, N., Ben-Chaim, H.M., Friedrich, S., Weiss, P.L.: Effectiveness of virtual reality for teaching street-crossing skills to children and adolescents with autism. Int. J. Disabil. Hum. Dev. **7**(1), 49–56 (2008). http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=psyc6&AN=2008-18791-009
24. *Lorenzo, G., Gómez-Puerta, M., Arráez-Vera, G., Lorenzo-Lledó, A.: Preliminary study of augmented reality as an instrument for improvement of social skills in children with autism spectrum disorder. Educ. Inf. Technol. **24**(1), 181–204 (2019). http://dx.doi.org/10.1007/s10639-018-9768-5
25. *Maskey, M., et al.: An intervention for fears and phobias in young people with autism spectrum disorders using flat screen computer-delivered virtual reality and cognitive behaviour therapy. Res. Autism Spectr. Disord. **59**, 58–67 (2019). https://doi.org/10.1016/j.rasd.2018.11.005
26. *Self, T., Scudder, R.R., Weheba, G., Crumrine, D.: A virtual approach to teaching safety skills to children with autism spectrum disorder. Top. Lang. Disord. **27**(3), 242–253 (2007). https://doi.org/10.1097/01.tld.0000285358.33545.79
27. *Strickland, D., Coles, C., Southern, L.: JobTIPS: a transition to employment program for individuals with autism spectrum disorders. J. Autism. Dev. Disord. **43**(10), 2472–2483 (2013).https://doi.org/10.1007/s10803-013-1800-4