Virtual reality (VR) interventions in cognitive rehabilitation among adolescents with autism spectrum disorder

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ABSTRACT

Technological devices are fast evolving. Millennials have grown with the devices and the internet, making them a very important target research group. The objective of this study is to provide an overview of the latest virtual reality (VR) interventions used in cognitive rehabilitation among adolescents with autism spectrum disorder (ASD). Due to the rapid technological advances, the systematic literature search was limited to publications from the last five years (2013 to 2017). In the review, only 3 studies were identified that used VR technology as a cognitive intervention tool among adolescents with ASD. Vocational skills, social competence and driving skill training were the categories where VR technology documented a peak of its usage. Due to the limited scope and the small sample sizes in existing research, the effectiveness of these interventions as rehabilitation or training tool still remains unproven. Recommended interventions are difficult to determine.

Keywords:

Autism spectrum disorder, virtual reality, virtual environments, adolescents, cognitive training, millennials

INTRODUCTION

Technological-based interventions have been exponentially growing in the last years. Applications designed for health care have been increasingly recognised as useful not only in remote areas, where health care services are limited, but also in all situations where the health specialist – patient interaction happens online. With the advent of affordable technological tools, there is a new opportunity to apply telemedicine to decentralize health treatments reaching more patients and improving lives around the world. New technological interventions are typically recognized as cost-effective.

The current generation of adolescents has been dealing with online technology and computers all their lives, and according to some researchers, visually presented information is a preferable form of support and learning also for many adolescents with autism spectrum disorder (ASD) (Shane & Albert, 2008; Odom et al. 2015). Still, the research and intervention literature has not been focusing on adolescents as much as preschool- and elementary school aged children (Wong et al. 2014). Currently, virtual reality (VR) is offering a new way of an active human-computer interaction within virtual environments that imitate closely real life (Riva, Mantovani & Gaggioli, 2004), which has been studied from the neuropsychological point of view even less.

This following work is organized by first shortly describing core developmental challenges and expectations in subjects with an autism spectrum disorder (ASD). Then, some of the evidence based interventions used in ASD rehabilitation are described, detailing the technology-based interventions, especially on virtual reality (VR). A systematic literature review is carried out in order to describe the latest trends of VR-based interventions used among 13-19 year-old adolescents with ASD, and to identify needs for future research.

Clinical presentation of autism spectrum disorder

Autism spectrum disorders (ASDs) are one of the most common neurodevelopmental disorders among children with the present prevalence estimate of 1.04% (95 % CI 0.99% - 0.108 %) (MacKay, Boyle & Connelly, 2016). The frequency of these disorders has increased throughout the last decades, and it is unclear whether this is entirely attributable only to the increased awareness of milder forms of the disorder among medical providers (DeFillips & Wagner, 2016). It has been also discussed that the increases in the prevalence estimates may reflect changes in definitions, concepts and service availability (Fombonne, 2009). Either way, it calls for more effective intervention procedures. ASD is characterized by complex behavioral phenotype and impairments in social communication, repetitive behaviours and restricted interests (APA, 2000). The concept of autism has been evolving during the last century. The newest classification of The Diagnostic and Statistical Manual of Mental Disorders (DSM-5) regards autism as a continuum, falling under one diagnostic classification, termed Autism Spectrum Disorder (ASD). DSM-5 now includes the option of describing more of the individual support one might need rather than the severity of ASD.

Interventions for autism spectrum disorder: Evidence-based practices and intervention outcomes

Only few studies have evaluated treatment approaches for teenagers and young adults with ASD, and only five studies mainly on medical interventions have proven to be of reasonable quality (Lounds Taylor et al., 2012). Louds Taylor et al. (2012) systematically reviewed intervention studies for adolescents and young adults (ages 13-30) presented in 1980-2011 identifying most of the studies poor

quality. In their review some improvement in social skills and functional behavior were suggested by a series of small scale studies focused on behavioral, adaptive skills and educational interventions that were evaluated as weak by the authors. In the developmental transition from childhood to adolescence the interventions focusing towards independent functioning or adaptive behavior should come more to the spotlight as there might emerge also new developmental challenges or symptoms (eg. vocational engagement or independent living) (Selzer, Shattuck, Abbeduto & Greenberg 2004). Wong et al. (2014) identified two main classes in their broad review on interventions used in autism spectrum disorder: focused intervention practices and comprehensive treatment models. With comprehensive treatment models they are referring to" a set of practices designed to achieve a broad learning or developmental impact on the core deficits of ASD". Focused intervention practices focus on a single skill or goal and occur during a shorter time period (Odom, Boyd, Hall & Hume, 2010). Wong (2014) found in their review (years 1990-2011) a total of 27 studies that were filling the requirements of evidence-based practices. Most of those studies had been focusing on pre-school children with outcomes of social skills (19 %), communication (21%), challenging behavior (19%) and social readiness skills (8%) while approximately 2% of the ASD intervention outcome had been about cognitive performance, such as intelligence, theory of mind, attention or executive function (Wong, 2014). Much less focus has been laid on the typically important concerns for adolescence like vocational skills needed for employment preparation (1%) or mental health (0,1%) (Wong, 2014).

Technological-based interventions

It is anecdotally known, that adolescents with ASD have a fascination towards technology and computers, yet the empirical research among ASD individuals has not been as strong as with typically developed peers (Mazurek, Shattuck, Wagner & Cooper, 2012). A growing number of studies have investigated diverse applications of technology-based interventions of children with autism (Goldsmith & LeBlanc, 2004). The development of technology has allowed the assessment methods and rehabilitation tools to evolve towards more and more naturalistic, real life conditions. This seems to be an important progressive step, as according to Neisser (1982) cognitive psychology has been suffering from the lack of ecological validity, the relevance of the used method or system relative to the "real" world. Keintz, Goodwin, Hayes & Abowd (2013) reviewed technology that has been designed for individuals with ASD identifying eight interactive technology platforms: personal computers, use of the web, shared active surfaces, mobile devices, sensor and wearable technologies, robotics, natural user interfaces and virtual reality. The growing number of technological interventions has led National Autism Center, a center for the Promotion of Evidence-based Practice (2009) to name this new group of different behavioral and educational approaches as "Technology-based treatment". The use of technological devices diminishes human error, as many programs include a built-in standardization and provide an opportunity for repetitions (Miller & Barr, 2017).

Virtual Reality (VR) and Virtual Environments (VE)

There are different definitions of virtual reality (VR) depending on if the focus is in the technological features or in describing the active participation of the individual within a computer-generated 3D-virtual world. Jaron Lamier was the first to use the term of virtual reality in 1986 and since then VR has been typically described as a group of technical devices including a head-mounted display, a computer with interactive 3D visualization and data gloves (Riva

et al. 2004). VR can also be described as a simulation of the real world, naturalistic environments using computer graphics (Wang & Reid, 2009; Rizzo, Schultheis, Kerns, Mateer, 2004). Virtual environments (VE´s) provide experiences that can help in either understanding concepts or learning to perform specific tasks by simulating the real world as it is or creating totally new worlds (Chittaro & Ranon, 2007). Rizzo et al. (2004) describe VEs "much like an aircraft simulator", with the difference that VEs can present simulations that" asses and rehabilitate human cognitive and functional processes under a range of stimulus conditions that are not easily controllable in the real world". In neuropsychology, the first discussions of the potential of VR technology and applications emerged in the mid 1990s (Pugnetti et al., 1995; Rizzo, 1994; Rose, Attree & Johnson, 1996). According to Goldsmith & LeBlanc (2004) virtual reality applications offer incomparable control over the environment, which allows health care professionals to arrange environments that promote the best learning and generalization. It also offers a safe and highly realistic environment to teach skills that are associated with some level of danger (e.g. stranger safety) when taught in the natural environment. VR technology is aligned with the visuospatial preference that is generally identified as a strength and main learning channel of students with autism spectrum disorder (Fernández-Herrero, Lorenzo-Lledó, Lledó Carreres, 2018).

Even though the research on the use of VR as an educational tool for ASD has started some 20 years ago, most of the scientific reports concentrate between the years 2010 and 2017 probably due to the level of development and affordability of the VR technology (Fernández-Herrero et al., 2018). The current research in VR technology within the last 10 years has focused for example on neurocognitive assessment, pain management, prevention and treatment of eating disorders, communication training, social skills training, vocational readiness training, psychotherapy and rehabilitation (Parsons et al., 2017). The publications of VR as an educational tool among autistic individuals have been mostly focusing on the learning of social skills (especially socially accepted behaviour), over those that deal with emotional skills (where the leading topic of research has been emotions recognition and regulation) (Fernández-Herrero et al., 2018). The investigation of VR as a cognitive rehabilitation tool among adolescents with ASD hasn't gained as much interest as among children which is surprising as computer-based tasks can actually be encouraging learning and motivation among youth with ASD (Parsons, Leonard & Mitchell, 2006). One of the worries has been, if individuals with ASD can understand and interpret the technology appropriately. Parsons et al. (2006) in their small, qualitative case-study observed and gathered comments from two adolescent boys with ASD while they were using VE-based environments. The researchers found that the participants seemed to interpret the scenes meaningfully, even though there were also signs of repetitive behaviors and literal interpretation of the scenes. The researchers found the results encouraging as the participants reported feelings of satisfaction combined with an ability to provide relevant examples how the VE could help them in the real world as well (Parsons et al., 2006).

Aims of the study

The aims of this systematic literature review were a) to explore the latest trends of VR-based interventions among 13-19 year-old adolescents with ASD, and b) to evaluate suggestions for future research.

METHODS

To identify all the studies that investigated the use of virtual reality in cognitive rehabilitation among adolescents with ASD, a search was conducted April 28th and April 29th 2018 in ANDOR (database portal in Tampere University, using ProQuest Summon index finding articles), PsycINFO and PubMed. The combination of search expressions including: "ASD", "autism spectrum disorder", "virtual reality", "cognitive", "rehabilitation or treatment" and "adolescent" was used. Manual search was also conducted in Google Scholar, but no additional articles were found with the criterion. Search concepts were selected by using MeSH and Termix browsers (Table 1). The description of the DSM-5 based autism spectrum disorder (ASD) was used in the search terms instead of wider diagnosis of

pervasive developmental disorders (eg. Asperger syndrome or PDD-NOS). Only articles that were published during the last five years (between 1 January 2013 and 31 December 2017) were considered for closer evaluation. The language was limited to English and the full text article had to be available in the database. In the search portal ANDOR the science field was also limited to psychology. With these criteria, 506 articles were found in the databases. The titles and abstracts of the resulting articles were screened first, and after that in the full-text review only articles relevant to the study were accepted. The following inclusion criteria were used: interventions that a) included interactions with virtual reality or virtual environment b) included a participant group with formally diagnosed ASD, c) had adolescent participants (mean age 13-19 years) d) assessed
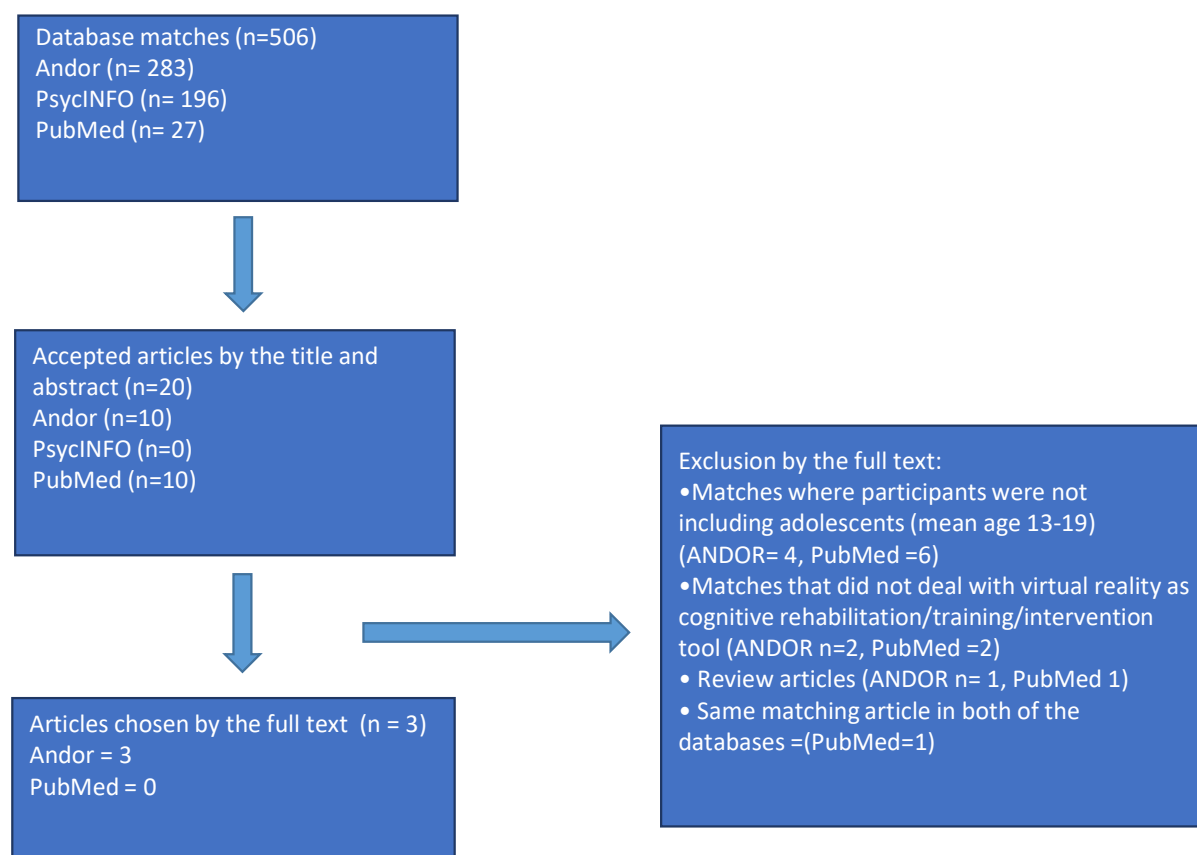

Figure 1. The process of database search. Screening progression and number of the articles.

training/rehabilitation or intervention. Exclusion criterion: a) studies that didn´t use virtual reality technology for rehabilitative/training or intervention b) review articles or meta-analyses. After careful evaluation, 3 articles were chosen for this mini review (Figure 1).

RESULTS

Table 1 shows the articles selected for the review. The first study (Cox et al., 2017)

used virtual reality driving simulation (VRDS) training to evaluate and assess improvement in driving performance, the impact of VR training on driving-relevant executive functions (response inhibition, working memory and dual tasking) and tactical skills with novel drivers with ASD. The driving licence reinforces independency in several ways, eg. maintaining and securing social relationships and work (Reimer, Fried & Mehler 2013). Compared to non-ASD individuals, people with ASD are known to have more problematic driving

Table 1. Studies investigating VR-based interventions in cognitive rehabilitation among adolescents with ASD (years 2013-2017)

Authors and the year of publication	Title of the publication	Aim of the Study	ASD participants in the study (n) and the mean age	Main finding(s) of the study
Cox, D., Brown, T., Ross, V. et. al. (2017)	Can Youth with Autism Spectrum Disorder Use Virtual Reality Driving Simulation Training to Evaluate and Improve Driving Performance? An Exploratory Study.	To investigate how novice drivers with autism spectrum disorder (ASD) differ from experienced drivers and whether virtual reality driving simulation (VRDST) training improves ASD driving performance.	51 novice ASD drivers, (M= 17.96 years)	VRDST significantly improved driving and EF performance over RT.
Strickland, D., Coles, C., Southern, L, (2013)	JobTIPS: A Transition to Employment Program for Individuals with Autism Spectrum Disorders.	Evaluated the effectiveness of an internet accessed training program (including virtual reality practice sessions) with high functioning Autism Spectrum Disorders.	22 participants with ASD or high fuctioning autism (M= 18.21, SD=1.03)	Method can improve employment related interviewing skills (especially verbal content skills) for individuals with ASD.
Lahiri, U., Bekele, E., Dohrmann, E. et al., (2015)	A Physiologically Informed Virtual Reality Based Social Communication System for Individuals with Autism.	Evaluation of an application of a novel physiologically responsive virtual reality based technological system for conversation skills in a group of adolescents with ASD.	8 adolescents with ASD (M = 15.88 years, SD = 2.18 years)	Improved performance and looking pattern within the physiologically sensitive system as compared to the performance based system.

*EF (executive functions)

behaviour compared to non-ASD individuals with poor motor coordination, social communication deficits, weaker central coherence and executive skills (Brooks et al., 2016). The VRDS has the benefits of providing a possibility for immediate feedback by keeping up the motivation for practice, and also providing a possibility to pause the activity for careful review and evaluation. This can be helpful for monitoring your own performance and self-awareness especially when it comes to executive skill problems (Rizzo et al., 2004). Enhancing motivation can be also created by the hierarchical delivery of stimulus, which allows the difficulty levels of the tasks to proceed gradually thus supporting positive reinforcement and identification, implementing, and modifying individual compensity strategies (Rizzo et al., 2004). In the research of Cox et al. (2017) novice drivers with ASD were compared to experienced drivers and whether virtual reality driving simulation training (VRDST) would improve the driving performance of ASD participants. Participants were randomized into three alternative variations of VRDST or routine training (RT). Cognitive domains of executive skills and tactical driving skills were assessed pre- and post-training. Standard VRDST included 8 to 12, 1 hour training sessions, where the participant had to proceed by passing each training module (10 modules) in order with a certain driving theme. A trainer demonstrated the task of the module to the participant beforehand and monitored performance with positive verbal feedback. Automated VRDST was similar to Standard version but instead of a trainer´s voice, provided real time simulator´s computerized auditory feedback (eg."too fast", "wide turn"). Eye tracking VRDST was using incorporated eye tracking with Standard VRDST. According to Cox et al. (2017), differential improvement in the tactical performance was evidenced by the use of Standard and Automated VRDST relative to RT, suggesting VRDST

as a potential tool for improving basic driving skills. The research did not find VRDST to be more effective fot routine training as it comes to driving relevant executive function improvement (only with working memory-arm/hand reaction time). It is worth pondering, if the normally presenting lack of real-world training distractions could be influencing the development of executive functions and enhancing the ecological value of this method (Rizzo et al., 2004). However, VRDST seemed to be a significantly better (better steering and speed control) tool by improving the tactical performance relative to routine training.

As it was previously mentioned, the popularity of using VR as a social skills training tool with ASD was also proved at this review as the two other studies were using VR training to improve social interaction in different settings. In the study by Strickland, Coles and Southern (2013) VR practice was used to teach appropriate skills required in a successful job interview for adolescents with ASD. The JobTIPS program is based on the concept of Theory of Mind (ToM), with the understanding that behind the behavior of ASD individuals, there is a lack of an ability to attribute mental states to themselves and to the others (Baron-Cohen, Tager-Fulsberg & Cohen, 2000). In their randomized study of 22 adolescents, half of the participants received virtual reality-based training following the initial interview while the other half did not. The participants randomized to the training group were guided to use JobTIPS interviewing program at their home computers. At the virtual office space the clinician used the interviewer avatar (an avatar is a graphic representation linked to a user to which will work as his/her identification in the virtual world) providing feedback about the initial interview providing concrete samples of desirable interview answers. Training included also guidance and feedback of participant´s non-verbal communication (eg. facial expressions and body language).

The participants were evaluated by independent raters, which focused their rates for both content and delivery of the interview. They found that the JobTIPS program was effective in teaching correct verbal performance, but the program did not improve the non-verbal communication combined with the speech (e.g. posture or facial expressions). Nevertheless the "empowering environment" of rehabilitation using VR can provide a safe setting to explore and experiment freely different emotions and thoughts without feeling threatened (Riva et al., 2004). The research setting had limitations with sample size. Results may be questioned also due to assessing the progress of vocational skills among highly motivated, volunteer boys only. The results might not be generalized to a wider scale of ASD.

In the third, small usability study that focused on the potential of VR-gaze-based system to improve social communication. Lahiri, Bekele, Dohrmann, Warren and Sarkar (2015) were aiming to focus more on the non-verbal behavior of communication. The authors presented a novel VR-based system that was designed to administer and alter social interaction and provide feedback based on two criteria: with objective task performance and dynamic physiological measures of eye gaze (Lahiri et al., 2015). Like in study of Strickland et al. (2013), Lahiri et al.(2015) were also pointing out the importance of not only achieving improved task performance, but also improved social communication skills and the ability to carry out conversation in an appropriate way, eg, with socially appropriate looking pattern. They designed a VR-based Adaptive Response Technology based system and evaluated conversational skills of 8 ASD adolescents. Pilot work for usability before actual evaluation included also 4 typically developed peers. The VR-based system involved three different modules. During the tasks, there were two different ways of interaction between avatar and the

participant. In a performance-based session (PS) the avatar´s role was only to respond and answer for the questions the participant asked. In the engagement-based session (ES) the system was also aware of the participant´s predicted behavior by the looking pattern and gaze related physiological signals. The first module (VR-based social communication task module) included 24 social tasks with avatars narrating personal, stories to the participants that were typically interesting for adolescents (eg. favourite sport). The second module (a real time eye-gaze monitoring module) captured gaze data with eye-tracker goggles while the participant was interacting with an avatar. The third module (individualized adaptive response module) used two adaptive VR-based systems for providing individualized responses for conversation (ES and PS). Conversation capabilities of the altered components hinge on 1) Performance-based session alone (PS) or 2) the composite outcome of performance and physiological metrics of foretold engagement (e.g. pupil dilation, gaze pattern, blink rate) (Engagement-based session (ES)). The results showed that each ASD and TD (typically developed aged matched controls) participant showed more improvement in terms of fixation towards the face of their virtual peers in the ES condition compared to the PS (Lahiri et al. 2015). The majority of these participants were ready to demonstrate changes in terms of additional viewing faces of virtual peers (avatars) for an extended period furthermore as playing higher whereas interacting with the ES system, vs. PS system. However, there should be cautious interpretation of the results as the sample size was very small (n=8) and proof-of-concept design was used in the study. The study was also limited to teenagers with average or higher than average intelligence, which limits the representativeness of the study. It also remains uncertain whether there is generalization to real-life in the skill im-

provement. According to the study more research is needed to understand the potential of VR platforms that can integrate physiological and engagement processes.

DISCUSSION

The systematic literature review yielded three studies that focused on VR-based interventions on adolescents with ASD, published in the last five years, it seems that there is a strong trend towards creating new technological equipment as most of the reviewed studies are pilot studies of new programs or applications using the newest VR or VE technology. Therefore, the research focusing on the effectiveness of these interventions as rehabilitation or training tools remains very limited and should be interpreted with caution. This makes it difficult to determine the recommended interventions. The technology and the use of VR have been developing strongly after 2010 and the field of research is still very novel. These factors contribute to the small sample sizes, thus diminishing reliability and generalizability. Much more research is also needed to evaluate the transfer of the improvements into real life. It was also surprising that there seems to be only few researches using VR technology in cognitive training among adolescents, even though this type of technology is of highly usage in this group. More research is needed to cover more widely different scales of cognitive functioning as the research is mainly focusing on adolescents with average or higher than average intelligence. In this research there were no studies of longer term impacts of the training. According to Lounds Taylor et al (2012) there is a general lack of adequate information on longer-term outcomes especially relating to achieving goals for independence and quality of life when it comes to adolescents and young adults with ASD.

Despite several technology-based interventions that aim to help the lives of children and adolescents with ASD, there have been questions about the risks for negative health outcomes related to the long screen times. The most recent studies are even raising the question whether the extensive audiovisual screen time would be explaining the rising prevalence of autism spectrum disorders by justifying their theory with the distorted development of neuroplasticity (Heffler & Oestreicher, 2016). As the sensory exposure is heightened by increased audio and visual input, the infants' neuronal pathways are more susceptible to specialization of non-social sensory processing than environmental exposures which are essential e.g. reading social cues. Major concerns have been raised over the fact that the various non-automatic cognitive efforts that are required to navigate or interact with the more demanding level VR technological devices could be a distraction within rehabilitation processes for adolescents with cognitive difficulties (Rizzo et al., 2004). Other researchers have been worried about the VE exposed childrens´ problems to differentiate real memories from VR-based memories (Segovia & Bailenson, 2009). Despite of all the existing benefits of VR, there is still a need for establishing the psychometric properties of VR interventions and assessment, and the added value for neuropsychological practices with normal and clinical populations needs to be verified via systematic empirical research (Parsons et al., 2017; Rizzo et al., 2004).

In conclusion, the purpose of the following mini-review was to determine the latest trends of VR applications among adolescents with ASD. Due to the very rapid development of the technical devices, the review was limited to last five years. In this study the accepted articles were very limited and the size samples were small. According to Newbutt, Sung, Kuo and Leahy (2017) the research with individuals with

ASD has been focusing on helping functional, social, personal and vocational skills. In the ASD literature younger school-aged children have been in the spotlight of early interventions and rehabilitation services. Surprisingly, based on the findings of both the present study and the large review of evidence-based practices used for children, youth and young adults (Wong et al, 2014) less focus has been pointed on adolescent research and services. Virtual reality applications seem still to be quite novel in cognitive rehabilitation, but in time the use of technology is likely to be more frequent also in the health care sector.

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