Supplementary Material

***Supplementary Table 1: Overview of studies using Virtual reality programs for individuals with neurodevelopmental disorders (n= 75 experimental studies)***

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| **Authors** | **Population** | **Purpose** | **VR technology** | **Results** |
| Abirached et al. 2011 | ASD | Examines effectiveness of game design of a serious game targeting social communication in ASD population. | Serious Game (LIFEisGAME). | * Pilot study. No data presentation other than the fact that participants responded well to the game. |
| Adams et al., 2009 | ADHD, TD | Evaluates the effectiveness of VR classroom (classroom version of a continuous performance task) to compare ADHD children with control subjects. | VR classroom version of Continuous Performance Task  (CPT). | * In the Virtual Reality presentation, the ADHD group performed worse than the control group and this difference approached significance. Virtual reality’s classification rate was better than standard CPT * ADHD participants were more affected by distractions in the VR classroom than control subjects. |
| Amaral et al., 2017 | ASD | Use of Virtual Reality P300-based Brain Computer Interface (BCI) paradigm in 3 EEG systems.  Comparison of   * 1 – g.Mobilab+ (active dry-electrodes, wireless transmission) * 2 – g.Nautilus (active electrodes, wireless transmission) * 3 – V-Amp with actiCAP Xpress dry-electrodes. | Brain Computer Interface (interactive immersive virtual-reality (VR) technology combined with the properties of P300 signals). | * The Nautilus system proved to perform the best (accuracy in the detection of P300, preparation time, speed and reported comfort) * Perspective of using this setup to train joint attention skills in ASD. |
| Bauminger et al., 2007 | ASD (High functioning  children with autism) | Pilot study presenting an intervention targeting social skills. | Story Table interface. | * Positive effect on the quality of social interaction and effect transfer to other tasks * Decrease in repetitive behaviors. |
| Bauminger-Zviely et al., 2013 | ASD | Evaluates the effectiveness of a collaborative technology intervention, combined with cognitive behavioral therapy. | Collaborative technology. | * Improvement in participants’ capacity to provide active solutions to social problems. * Better understanding of collaboration and social conversation. Some improvement in Theory of Mind. |
| Beaumont et al., 2008 | ASD (Asperger syndrome) | Evaluates the effectiveness of a multi-component social skills intervention. | Junior Detective Training Program (Computer game). | * Improvements in social skills for ASD children in intervention group indicated:  1. by parent-report and teacher-report measures 2. Participants’ performances on post-intervention as they proposed better emotion-management strategies for story characters  * No difference between intervention and control group of ASD children on facial expression and body-posture recognition measures. |
| Bekele et al., 2014 | ASD | Assess effectiveness of virtual environment targeting facial affect recognition in ASD population. | VR environment. | * ASD participants performed as well as TD (accuracy in basic facial affect recognition) * Nevertheless, ASD participants were less confident about their responses. * ASD participants presented substantial variation in gaze patterns. |
| Benzing et al., 2017 | ADHD | Evaluates the effectiveness of an exergaming intervention on EF, ADHD symptoms and motor abilities. | VR technology (exergaming intervention). | * Improvements in different domains including executive functions, and motor abilities. |
| Bernardini et al., 2014 | ASD | Evaluates the effectiveness of a serious game targeting practicing social communication skills. | ECHOES (serious game). | * The ECHOES platform seems to be promising for training social communication skills according to the preliminary results, obtained after an extensive evaluation. * No significant transfer of increased social responsiveness or initiations to real-world context noted for all participants. |
| Bernard-Opitz et al., 2001 | ASD, TD | Evaluates the effectiveness of a computer training program targeting social problem solving in  ASD population. | Computer program. | * ASD participants produced fewer alternative solutions than control subjects. * Nevertheless, the ASD group’s production of alternative solutions increased across probe sessions, suggesting that thanks to the computer interface, problem-solving strategies can be taught to children with autism. |
| Bioulac et al., 2012 | ADHD | Investigates and evaluates the task effects on performances of ADHD and control participants in a Virtual Classroom (VC) over time. | VR Classroom. | * ADHD participants showed a performance decrement whereas controls sustained performances over time in the CPT-VRC * Performances in the VC correlated with CPT II measures. |
| Bölte et al., 2002 | ASD | Presents the design and the evaluation of a computer-based program targeting facial recognition of emotions. | Computer-based  Program. | * Performance improvement for training condition participants *only* in the affect recognition task. |
| Bölte et al., 2006. | ASD (High-functioning autism) | Evaluates the effectiveness of a computer-based program to teach facial affect identification.  Examines if activation of the Fusiform Gyrus (FG) is related to successful facial affect recognition training in ASD population. | Computer-based program, Frankfurt Test and Training of Facial Affect Recognition (*FEFA).* | * No significant FG activation changes observed. * Behavioral improvements observed for participants in training group, as well as higher BOLD fMRI signals in the superior parietal lobule and maintained activation in the right medial occipital gyrus. |
| Bul at al., 2016 | ADHD | Examines effectiveness of training targeting daily life skills of ADHD children. | Serious Game (Plan-It Commander). | * Greater improvements in time management skills, in social skill of responsibility and working memory for intervention group. * Intervention group maintained or improved positive effects in the last 10 weeks of the study. |
| Bul et al., 2018. | ADHD | Examines efficacity of a serious game intervention for different subgroups of ADHD children. | Serious Game. | * The subgroup of girls benefited from the serious game, showing improvements in planning/organizing skills. * The subgroup of boys, presenting lower baseline levels of hyperactivity and higher levels of CD symptoms, also benefited from this intervention. |
| Chen et al., 2022 | ASD | Evaluates effectiveness of an executive function training system. | Comprehensive Attention Training System (CATS). | Preliminary evidence of training’s effectiveness. The group receiving CATS improved on EF. Additionally, due to CATS training, improvements were observed in long-term communication skills. |
| Cheng et al., 2010 | Intellectual and developmental disabilities (IDD) | Evaluates effectiveness of 3D-emotion system intervention for IDD population. | 3D-emotion system. | * 3 participants showed positive effects. |
| Cheng et al., 2012 | ASD (pervasive developmental disorder) | Practices Joint attention skill in VR environment. | Joint Attention Skills Learning (JASL) systems - skills of pointing, showing, sharing things and behavior interaction with data glove. | * Experiment results show improvement in joint attention skills as well as effect in the daily life after practicing the JASL system. |
| Cho et al., 2002 | ADHD | Highlights the potential of using Virtual Reality in a cognitive training program targeting attention. | VR classroom. | * Confirmation of effectiveness of immersive VR with cognitive training for attention enhancement. |
| Cho et al., 2004 | ADHD | Evaluates the effectiveness of neurofeedback, combined with Virtual Reality, in decreasing ADHD symptoms (level of inattention, impulsiveness). | VR classroom. | * Both groups (VR and non-VR neurofeedback training) achieved better performances in the CPT in post-test evaluation. No significant difference was observed for the control subjects. * VR group presented a tendency to get better results than the other two groups, suggesting that immersive VR is applicable to neurofeedback and is promising for the rehabilitation of ADHD symptoms (inattention and impulsiveness). |
| Deriso et al., 2012 | ASD | Examines effectiveness of an intervention system targeting facial expression perception and production in ASD population. | Game: Emotion Mirror. | * No data presented. |
| de Vries et al., 2015. | ASD | Investigates effectiveness of two EF training (working memory and cognitive flexibility) conditions in ASD population. |  | * Improvement in working memory, cognitive flexibility, attention, and on parents’ ratings. * No improvement in inhibition. * No significant differential intervention effects. * Training in this form probably not suitable/ appropriate for ASD population. |
| Didehbani et al., 2016 | ASD | Evaluates the effectiveness of a Virtual Reality Social Cognition Training in ASD individuals. | Virtual Reality Social Cognition Training (VR-SCT). | * Improvements in participants’ performances on  1. emotion recognition 2. social attribution 3. executive function of analogical reasoning. |
| Dovis et al., 2015 | ADHD | Investigates the efficacy of a gamified EF training intervention. | Gamified EF training with Braingame Brian -BGB. | * Improvements in inhibition and visuospatial short-term-memory and WM on full active condition * Improvements in inhibitory performance and interference control in the full-active- and the partially active condition. * Transfer to untrained EFs and behaviors was mostly nonspecific. |
| Escobedo et al., 2012 | ASD | Evaluates the effectiveness of a mobile assistive application MOSOCO. | Mobile assistive application: augmented reality application  inspired by the Social Compass  curriculum: 6 social skills | * Improvement in practicing and learning social skills in real-life situations after MOSOCO use. * Increase in quantity and quality of participants’ social interactions * Decrease in social and behavioral missteps. |
| Faja et al., 2007 | ASD, TD | Evaluates effectiveness of a computerized face-specific training targeting face processing strategies. | Computerized Face Program. | * All participants in training condition achieved behavioral criterion concerning expertise in face recognition. * ASD trained group showed significantly greater sensitivity to second-order configural relations. * No difference observed between training condition and control condition in the measure of holistic processing. * According to the study’s results, improvement in face processing is feasible through training in ASD individuals. |
| Fernandes et al., 2011 | ASD | A) Describes a serious game targeting recognition and expression of emotions through facial expressions  B. Presents a study analyzing children’s preferences concerning a game’s characters, and a pilot study (ASD participants). | LIFEisGAME (serious game). | * Study concerning preferences about characters. Participants seem to prefer:  1. animals (in 2D or 3D version) 2. 3D characters (for animals they prefer photorealistic characters) 3. In order: familiar animals, 3D unfamiliar animal cartoon, 2D animal cartoon, photorealistic animal  * Pilot study * Children reacted positively to the game in the first session. Nevertheless, some participants did not want to play in the second session. * Participants experienced some problems with the touch screen due to the small size of the curve handles. |
| Fletcher-Watson et al., 2016 | ASD | Evaluates effectiveness of an early intervention targeting social communication skills in preschoolers. | FindMe app. | * No improvement in real-world social communication skills was observed. |
| Frolli et al., 2022 | ASD | Comparison of a VR social training and a traditional social training. | VR program. | * Acquisition of the recognition of primary emotions did not differ in the VR social training and in the traditional social training. Nevertheless, acquisition of primary and secondary emotions was faster in the VR training group. |
| Ghanouni et al., 2019 | ASD | Creation and validation of socio-emotional stories in a virtual environment. | VR program. | * Validated a library of 75 short socio-emotional stories. * **No data presentation.** |
| Gordon et al., 2014 | ASD | Examines effectiveness of a novel computer game targeting production of posed expressions. | FaceMaze computer game (computer recognition system). | * ASD group’s ‘‘happy’’ and ‘‘angry’’ expressions were rated as better in quality in post-test. * ASD group expressions were rated equally with TD group in post-test. |
| Grynszpan et al., 2008 | ASD | Presents the design and evaluates training software, targeting specific communicative disorders. | Computer game. | * ASD participants performance was worsened on the richer multimedia interfaces. Participants seem to lack capacity of organizing the multimodal sources. |
| Grynszpan et al., 2012 | ASD (High Functioning Autism  Spectrum Disorders HFASD) | Evaluation of Self-monitoring eye motion VR task (two conditions: free visual exploration and guided exploration), as atypical visual behavior is probably responsible of social misunderstandings and difficulties of ASD individuals. | VR task and eye tracking  (eye-tracking system and a gaze-contingent lens display). | * ASD group presented weaker modulation of eye movements, highlighting impairments in gaze self-monitoring. |
| Gutiérrez-Maldonado et al., 2009 | ADHD, TD | Evaluates the effectiveness of VR technology to assess attentional impairments in ADHD population. | VR Continuous performance task (CPT). | * Efficacy of VR-CPT to assess attentional difficulties. ADHD group performed significantly worse than control group. * Differences were observed in auditory as well as visual tasks (and became more evident during the presence of distractors). |
| Herrera et al., 2008 | ASD | Evaluates the effectiveness of VR training, targeting the understanding of pretend play. | VR-based learning environment (virtual supermarket) | * Improvement in pretend play abilities for both participants * Generalization of acquired capacity for one participant. |
| Hopkins et al., 2011 | ASD | Evaluates the effectiveness of “FaceSay”, a computer-based training, targeting social skills. | Computer-Based Intervention, “FaceSay”. | * High-Functioning Autism (HFA) participants improved their performance in all domains: facial recognition, emotion recognition, and social interactions. * Low-Functioning Autism (LFA) participants’ performance was improved in two out of three domains (emotion recognition and social interactions). |
| Ip et al., 2018 | ASD | Evaluates the effectiveness of a VR enabled program targeting emotional and social adaptation skills. | 4-side (projection-based) immersive VR system | * Improvement in primary measures (emotion expression, regulation and social-emotional reciprocity) * No difference observed on secondary measures. |
| Jung et al., 2006 | ASD, TD | Presents the development and evaluates the effectiveness of a program of sensory integration therapy based on VR-TIS. | VR-TIS (VR-SIT): Sensory Integration Therapy based on the Virtual Reality Tangible Interaction System.  Measurement of three components:  coordination ability, social skills training, sensory integration therapy. | * TD group performed significantly better than ASD group on coordination ability measurement, as well as on social skill training. * Potential of using VR-SIT for the assessment and the therapy of ASD individuals. |
| Ke et al., 2013 | ASD | Presents the implementation and evaluates the effectiveness of a virtual-reality program, targeting social interaction and communication. | Computer-generated, three-dimensional representation of  Real-life environment. | * During the intervention, participants’ performance was improved in responding, initiation, greeting as well as positive conversation-ending. * Social competence measures, used after the intervention, highlighted a transfer effect. |
| Ke et al., 2022 | ASD | Examines effectiveness of a virtual reality (VR)–based social skills learning environment for ASD population. | Desktop VR learning environment. | * Improvement in social skills performance from the baseline to the intervention phase. |
| Kim et al., 2015 | ASD (higher functioning autism spectrum disorder), TD | Demonstrates the design of a VR task, targeting assessment of social motivation (participants’ preference for interpersonal distance to social stimuli) and emotion perception in children with ASD. | Virtual-reality emotion sensitivity test V-REST (presented in Kim et al. 2010). | * ASD (HFAS) participants showed significantly less approach behavior to the positive happy expression than TD group. * Facing negative emotions, ASD, as well as TD group, presented a withdrawal behavior. * No differences between the two groups were observed in recognition accuracy. |
| Lacava et al., 2007 | ASD | Evaluates the effectiveness of an assistive technology.  Targeting Emotion Recognition (ER). | Computer software  Mind Reading: The Interactive Guide to Emotion. | * Improvement in emotion recognition (basic and complex) based on face and voice elements. |
| Lahiri et al., 2012 | ASD | Describes development of a VR-based interactive system with Gaze-sensitive adaptive response technology.  Presents preliminary results. | VR-based interactive system. | * Pilot study highlighting potential of this novel VR based system. |
| Lee et al., 2001 | ADHD | Develops a VR system targeting enhancement of ADHD. Evaluates the effectiveness of this VR system. | VR Therapy system/ VR program | * Decrease in errors of omission or commission for VR group, suggesting decrease in participants’ inattention or impulsivity. |
| Liu et al., 2017 | ASD | Evaluates the effectiveness of a Brain Power System (BPS), targeting social communication, and the presence of stereotypies. | Brain Power System (BPS):  *Face Game (smart glasses augmented reality.* | * Improvement in non-verbal communication, eye contact, and social engagement. * Decrease in ASD symptoms at 24-h post-intervention (irritability, lethargy, stereotypy, hyperactivity, and inappropriate speech). * Findings support the feasibility, usability, and tolerability of smart glasses system. |
| Lorenzo et al., 2016 | ASD | Presents the design and application of a new immersive VR system, targeting training of emotional skills. | Immersive VR system. | * Significant improvement in participants’ emotional competences. |
| Mitchell et al., 2007 | ASD | Evaluates the effectiveness of a Virtual Environment. | Virtual Environment (VE) of a *café.* | * Potential of VR for teaching social skills, as participants showed improvements in judgments and reasoning. |
| Moore et al., 2005 | ASD | Exploratory empirical study aiming to assess ASD participants’ capacity to recognize basic emotions represented by a humanoid avatar. | Collaborative virtual environment. | * The great majority (over 90% of participants) recognized emotions displayed by avatar representations. |
| Muhlberger et al., 2020 | ADHD, TD | Comparison of ADHD children (medicated and unmedicated) and healthy children in Virtual Reality Classroom (CPT-VRC). | Virtual Reality Classroom (CPT-VRC). | * Potential of VR technology to evaluate ADHD symptoms. * Unmedicated ADHD group committed more omission errors and had slower reaction times than the healthy group. * Unmedicated ADHD group reaction time presented higher variability than both medicated ADHD and healthy group. |
| Mundy et al., 2016 | ASD, ADHD, TD | Investigates the hypothesis of atypical information processing, during joint attention, for ASD individuals. | VR paradigm (combined eye-tracking and virtual avatar technology). | * ADHD and TD groups displayed significantly better recognition memory for pictures studied in an Initiating Joint Attention (IJA) rather than a Responding to Joint Attention (RJA) condition. This effect was not observed in the ASD group. * ASD group recognized fewer pictures from the IJA condition than control groups. This difference was not observed in RJA condition. |
| Negut et al., 2017 | ADHD | Examines the diagnostic validity of Virtual classroom Continuous Performance Tests (CPT). | Virtual Classroom-CPT (VC). | * Performance of ADHD participants was lower than TD children with a) more errors of commission and omission) b) slower target reaction times. * Participants in Virtual Reality condition presented longer reaction times than participants in the traditional computerized one. * Auditory distractors impacted attention performance of ADHD participants. This effect was not observed in the case of TD children. |
| Nolin et al., 2016 | ADHD | Evaluates the validity and reliability of the ClinicaVR: Classroom-(CPT).  Investigates the sense of presence and cyber sickness as well as the potential effects of gender and age on CPT. | ClinicaVR: classroom-(CPT). | * Results highlight concurrent and construct validity of ClinicaVR. |
| Parsons et al., 2004 | ASD, TD | Evaluates effectiveness of virtual training, targeting social skills in ASD population. | Virtual Environment: Virtual *café.* | * Results support evidence that understanding personal space is probably impaired in autism, as ASD participants presented more socially inappropriate behaviors (e.g. bumping into, or walking between, other people) than TD participants. * Potential of Virtual environments for social skills training as the performance of ASD participants was significantly improved after only a few training sessions. |
| Parsons et al., 2006 | ASD | Presents a case-study of two ASD adolescents using a virtual cafe ́ and bus environment. | Computer-based Virtual Environments : virtual cafe ́ and bus. |  |
| Parsons et al., 2007 | ADHD, TD | Use of VR classroom to assess attentional performance in ADHD children. | VR classroom. | * ADHD participants presented more omission errors, commission errors, and overall body movement than TD participants. * ADHD participants’ performance more impacted by distractors (auditory classroom sounds, visual or mixed audio/visual). * Correlation of VR classroom measures with traditional ADHD assessment. * Simulator sickness was not reported. |
| Parsons, 2015 | ASD | Demonstrates how factors such as the real-world context contribute to the design of a Collaborative Virtual Environment (CVE) targeting communicative perspective-taking skills in ASD population. | Collaborative Virtual reality Environment (CVE). | * Improvement in ASD participants’ reciprocal responses and collaboration skills. * CVE presents high potential for a technology-based educational intervention. |
| Pollak et al., 2010 | ADHD | Measures the effect of methylphenidate (MPH), by using continuous performance test embedded in virtual reality (VR-CPT). More precisely, compares ADHD participants’ performance on VR-CPT while on and off methylphenidate (MPH).  Compares the VR-CPT to a Test of Variables of Attention (TOVA). | Continuous performance task  (CPT) embedded in a virtual reality (VR) VR-CPT. | * MPH effect:   A) fewer omission errors on the VR-CPT compared to the no VR-CPT and the TOVA  B) Concerning the other CPT measures, a similar degree of decrease was reported on all types of CPT.   * VR-CPT was rated as more enjoyable by the participants. |
| Rajendran et al., 2000 | ASD (Asperger’s syndrome) | Evaluates the effectiveness of a computer-mediated role-taking experience, targeting interpersonal understanding, executive skills and verbal abilities.  Compares ASD participants’ performance to individuals with emotional and behavioral difficulties. | Computer mediated: The Bubble Dialogue program. | * Improvement in executive function for ASD participants * No improvement in ASD participants’ performance in interpersonal understanding * Only one of the Bubble Dialogue scripts, generated by the ASD group, was different from the scripts generated by the group of individuals with emotional and behavioral difficulties. |
| Ravindran et al., 2019 | ASD | Evaluates feasibility of using Floreo’s Joint Attention Module. | Floreo’s Joint Attention Module. | * Floreo’s Joint Attention Module was well tolerated by participants. * Improvements in fundamental joint attention skills. |
| Rice et al., 2015 | ASD | Evaluates effectiveness of a computer-assisted social skills intervention, targeting ASD population. | *FaceSay (computer-assistedprogram).* | * Performance of intervention group was improved on affect recognition and mentalizing skills. Moreover, these improvements were also reflected in certain generalized social-skills abilities. * Authors conclude that computer -assisted intervention, training face processing skills, can improve performance in other cognitive and social domains. |
| Rizzo et al., 2000 | ADHD | Highlights the design of a virtual “classroom attention” assessment task. | VR classroom. | * Presentation of the environment. * Experimental phase presented but no data. |
| Rodríguez et al., 2018 | ADHD | Compares results of a Virtual Reality Continuous Performance Test (Aula Nesplora) with a traditional CPT, both targeting ADHD population. | VR CPT (Aula Nesplora). | * VR CPT (Aula Nesplora) predicts ADHD presentation better than traditional one. * VR-CPT differentiates better between ADHD and non-ADHD students. |
| Serret et al., 2014 | ASD | Evaluates effectiveness of a computer game targeting emotion recognition in a heterogeneous ASD group. | JeStiMulE: computer game. | * Findings highlight adaptability, effectiveness, and efficiency of JeStiMulE, as in 30 out of 35 conditions a significant increase was observed after training. * JeStiMulE appears to be a promising tool to train emotion recognition also for individuals with Low Functioning Autism. |
| Silver et al., 2001 | ASD | Evaluates the effectiveness of a computer program, targeting a) recognition and b) prediction of others’ emotional responses. | Computer program. | * Errors decrease between pre and post-test for participants in training group (ASD participants receiving computer-based training). * Better performance for training group than control group (ASD participants not receiving computer-based program) on Emotion Recognition Cartoons and Strange Stories. * Scores improvement for both groups on Facial Expression Photographs. * No significant differences between two groups in pre-test. |
| Skalski et al., 2021 | ADHD | Evaluates effectiveness of hemoencephalographic (HEG) BFB with VR in children with ADHD. | Hemoencephalographic (HEG) BFB. | * Effect of EG BFB with VR in treating attention deficits. More precisely, better results obtained in this condition compared to standard 2D HEG BFB. |
| Swettenham,  1996 | ASD, TD, ID (Down Syndrome) | Evaluates the effectiveness of a Theory of Mind task. | Computer version of the Sally-Anne false belief task. | * All groups (ASD, Down's syndrome, Controls) pass the Close Transfer Tasks without significant differences. * Performance of all three groups was maintained in the 3-month follow up. * Participants of ASD group demonstrated more difficulties than other groups in the distant transfer tasks. Their performance was not improved in the follow up. |
| Tanaka et al., 2010 | ASD | Evaluates the effectiveness of a training intervention, targeting face recognition skills. | Computerized game: Let’s Face It! Program. | * This short-term intervention produced improvements in ASD participants face recognition skills as training group showed improvements:   a) in analytic recognition of mouth features.  b) in the holistic recognition of a face (based on its eye features). |
| Vahabzadeh et al., 2018 | ASD | Evaluates the effectiveness of the Empowered Brain system, targeting the decrease of ADHD-related symptoms in participants with ASD. | Empowered Brain system. | * Decrease of ABC-H scores (Aberrant Behavior Checklist-Hyperactivity) for some participants (6/8) at 24 hours after the intervention. * Decrease of ABC-H scores for all participants (8/8) at 48 hours. |
| Wang et al., 2016 | ASD | Evaluates the experience of embodied presence, embodied copresence and embodied social presence while practicing various learning activities. | Collaborative Virtual Learning Environment (CVLE) – iSocial. | * ASD participants achieved:  1. embodied presence and embodied copresence in most of the Naturalistic Practice activities used during the study. 2. The same effect was not observed for embodied social presence |
| Weerdmeester et al., 2016 | ADHD | Examines feasibility and effectiveness of an intervention targeting ADHD symptoms. | Full Body Game: “Adventurous Dreaming Highflying Dragon’’. | * Greater improvement of ADHD symptoms in the intervention group. * Both groups improved equally in fine motor skills and showed a deterioration in number of hits (assessing sustained attention) on the go/no-go task. |
| Williams et al., 2012 | ASD | Evaluates effectiveness of an emotion training intervention targeting ASD population with a range of intellectual ability . | Transporters. | * Limited efficacy. Participants in intervention group improved in the recognition of anger (comparing to control group). Improvement was maintained at 3-month follow-up. * No generalization in TOM or other social skills. |
| Yan et al., 2008 | ADHD | Presents the design and the effectiveness of a neurofeedback (NFB) system, using VR to create appropriate feedback information. | Brain Computer Interface (BCI) Neurofeedback (NFB) - Virtual Reality (VR) system. | * Improvement in participants’ attention skills. |
| Yeh et al., 2012 | ADHD | Presents the development of a VR assessment, targeting attention skills. | VR classroom. | * Presentation of the developed task (listening test, CPT test, executive test, and visual memory test). * **No experimental phase.** |
| Yuan et al., 2018 | ASD | Evaluates the effectiveness of a VR training program, targeting emotional and social skills. | Cave Automatic Virtual Environment (CAVE). | * Improvement in:  1. emotion expression and regulation 2. in social interaction and adaptation. |
| Zhu et al., 2011 | ASD | Evaluates a training program, targeting mirror neuron functions in ASD population. | A brain–computer interface (BCI) combined with VR technology. | * **No data presentation.** |

***Supplementary Table 2: Overview of reviews and meta-analysis reporting use of Virtual reality programs on individuals with neurodevelopmental disorders (n=20, 18 reviews and 2 meta-analysis).***

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| Bashiri et al., 2017 | ADHD(review) | Highlights the potential of using VR in the rehabilitation of ADHD population. | VR Classroom, VR games | * Findings suggest that rehabilitation of ADHD symptoms can be achieved in VR programs due to the presence of stable and controlled stimuli allowing steady progress, feedback-focused, haptic-based interaction, and immediate responses. * Virtual Reality improves users' motivation and allows embodiment of different neuropsychological tests, facilitating assessment and rehabilitation strategies. * Improvements are reported in ADHD participants’ behavioral and cognitive skills. |
| Chen et al., 2022 | ASD (systematic review) | Reviews Extended Reality and telehealth interventions for children and adolescents with ASD. | Extended Reality and telehealth interventions. | * Reviewed 112 studies. Authors presented positive improvements observed in numerous domains: social interaction, acceptance, and engagement, communication and speech, emotion recognition and control, daily living skills, problem behavior reduction, attention, cost reduction, anxiety symptom reduction, pretend play, contextual processing, match to sample skill, and insomnia control. * Of the studies reviewed, 12, categorized as qualitative studies, and 108, categorized as quantitative studies, used VR. * 32 studies targeting social interaction and emotion recognition. |
| Cibrian et al., 2022 | ADHD (review) | Reviews technological interventions targeting self-regulation behaviors and emotions for ADHD population. | Different technological interventions (personal computers, virtual and augmented reality, robots, etc,). | 36 papers (9 serious game and 4 Virtual Reality). Authors excluded papers using serious games that focused on cognitive training. Concerning VR only one study targeted cognitive remediation improvement in ADHD symptoms.   * Most studies presented technologies suspended in the design and prototyping phases. * Studies that included robust technologies highlight promising implications for self-regulation in ADHD population. |
| Derks et al., 2022 | ASD and ID (review) | Reviews effectiveness of serious games targeting social and cognitive skills of children with an intellectual disability (ID) and/or [autism spectrum disorder](https://www.sciencedirect.com/topics/psychology/autism-spectrum-disorder) (ASD). | Serious games. | * 11 studies included. * Improvements in targeted domains (adaptive and cognitive functioning) for participants (children) with ID or ASD. * Nevertheless, authors highlight that heterogeneity was moderate to high and significant. |
| Grossard et al., 2017 | ASD (review) | Reviews serious games, targeting training of social interactions in ASD individuals. | Serious Games | * Findings suggest that serious games:  1. are promising for training social interaction (e.g. training on many different social skills, use of diverse contexts and situations, resemblance with real life situations) 2. have some limitations (most games target High-Functioning individuals, clinical validation not always highlighted or rarely compared to medical standards; game design is not always described, etc). |
| Howard et al., 2020 | (meta-analysis) | Evaluates the effectiveness of VR training programs, targeting social skills as well as the effect of some moderating variables. | VR | * Improvement in developing social skills was greater on VR training programs than alternative training. |

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| Irish, 2013 | ASD (review) | Investigates effectiveness of single-user virtual environments (SVEs), targeting social communication skills in ASD population. | Single-user Virtual Environments (SVEs). | * Small number of researchers focus on SVEs. Thus, and besides the fact that outcomes of these studies are promising, we can’t conclude on SVEs’ efficacy. * Researchers argue in favor of a multi-component intervention approach. |
| Lakes et al., 2022 | ADHD (review) | Reviews Digital Health Interventions for ADHD population. | Technology used: serious games or e-learning, the web, mHealth, telehealth, and augmented or virtual reality. | * 51 studies included in this review. * 12 clinical trials reported positive outcomes. |
| Loh et al. 2022 | ADHD (review) | Reviews modalities in ADHD assessment. | Modalities reviewed:  Questionnaires/rating scales, P*hysiological signals, game simulation and performance tests (including VR system).* | * Concerning G*ame simulation and performance tests, 4 studies were included. One study used VR system (Yeh et al. 2020).* |
| Mazon et al., 2019 | ASD (review) | Reviews design weaknesses of Technology Based Interventions research by examining reliability, consistency, durability and generalization of measurements used. Comparison of two cores of studies: Therapeutic Effectiveness (TE) and Technology Usability (TU). | Technology-based interventions (eg computer,robot) | * 31 studies selected: 22 on *Therapeutic Effectiveness (TE)*, 6 on *Technology Usability (*TU), and 3 on both TE-TU. * Few studies reached the standards of evidence-based practices (i.e. reliability, consistency). * TE studies provided more evidence of reliability than the other two types of studies (TU and TU-TE studies). |
| Negut et al., 2016 | meta-analysis targeting ADHD patients, healthy participants, and patients with acquired disorder | Reviews studies comparing VR assessment and classical or computerized assessment. | virtual reality, classical or computerized assessment tools | * 13 studies included. 2 studies with ADHD population (Pollak et al. 2009, 2010) * Cognitive performance obtained in VR poorer than classical assessment, probably due to increased level of complexity and difficulty presented in VR. |
| Rizzo et al. 2009 | (review) | Highlights the use of virtual environments targeting attentional training as well as their use for applications in other clinical targets. | Virtual classroom. | * VR Classroom initially used with ADHD participants. Findings suggesting that VR-C is an efficient tool to assess attentional skills. * Development of other applications such as a) The Virtual Stroop test b) view system to study eye-tracking c) assessment of anxiety and use for therapy purposes in adolescents with social anxiety disorder, etc. * Use of VR Classroom seems to be promising for assessment and rehabilitation in different medical and psychological domains. |
| Vajawat et al., 2021 | Psychiatric population (among them ADHD and ASD patients) (review) | Reviews digital game-based interventions used in psychiatry and more precisely novel modes of Digital Mental Health Interventions (DMHI). | DMH interventions included: psychotherapeutic techniques (mindfulness training, virtual reality based exposure therapy, biofeedback), cognitive remediation (e.g. for ADHD population), tele-psychiatric social work.  2 studies, using game-based intervention for neurodevelopmental disorders, were included. | * Potential of Gamification in mental health interventions. Gamification is already used in preventive as well as therapeutic interventions with promising results. Use of Virtual Reality (VR) in conjunction with digital gaming shows promising results. |
| Valentine et al., 2020 | (review) | Describes technology (VR, videos, mobile app, robots, etc.) used to assess Neurodevelopmental Disorders as well as to treat symptoms. | 5 studies using VR for ASD population. | * Studies includes show clinical effectiveness. Nevertheless, some of these studies have poor quality ratings. |
| Vaughan et al., 2016 | Population not specified **(**review) | Examines the use and effectiveness of self-adaptive technologies (systems able to respond to changes) within virtual reality trainings. | VR | * Use in five domains/cores: a) medical VR-based training, b) industrial and commercial, c) serious games, d) rehabilitation, e) collaborative and remote VR training. |
| Wainer et al., 2011 | ASD (review) | Reviews use of innovative technology (interactive computer programs and virtual reality) to develop interventions targeting social and communication skills in ASD population. | Computer technology | * Literature presented has a more descriptive or exploratory nature. Nevertheless, it summarizes the initial studies and their findings. |
| Wang and Reid, 2011 | ADHD, ASD, cerebral palsy disorders (review) | Evaluates effectiveness of VR systems, targeting primary impairments of ADHD, ASD, and cerebral palsy disorders. | VR systems | * Three major categories of VR display systems, based on the type of user and computer interaction): a) feedback-focused interaction, b) gesture-based interaction, c) haptic-based interaction. |
| Wass et al., 2014 | ASD (review) | Reviews effectiveness of cognitive training technology-based in ASD population. | Technology- enhanced interventions | * Improvements in targeted skills during the computerized training. * Absence of generalization to more naturalistic settings/real life situations. |
| Wieckowski et al., 2017 | ASD, TD, Cerebral palsy (review) | Reviews technology applications (virtual reality, computer-based intervention) targeting social communication in children and adolescents | Any technology, tool, device, or procedure | * Most studies target ASD population, “ignoring” other clinical populations suffering from social communication impairments. * Few studies explore reception of non-facial communication,   37 studies found using VR or computer-based intervention for ASD population |
| Whyte et al., 2015 | ASD (review) | Reviews principles of serious game design and their use in trainings targeting ASD population. | Serious Game | * Little evidence of generalization of trained skills to naturalistic settings/real life situations. |

Supplementary Table 3: Presentation of TOM or EF assessment studies’ quality (N=16)

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| --- | --- | --- | --- |
| **Authors** | **Research design: Clinical (ASD, ADHD) and Typical Development (TD) population/ sampling / Age** | **Procedure: Assessment (Duration, VR or non-VR task, neuropsychological tests)**  **Training (Duration, VR or non-VR training, Number of sessions, Type of Feedback)** | **Evaluation study quality** |
| Adams et al., 2009 | Population: N= 35   * Clinical: 19 ADHD (boys) * TD: 16 age-matched TD   Age: 8 to 14 years. | 1. **Assessment of attention (VR or non-VR task):**  * Standard continuous performance task (The Vigil -Psychological Corporation, ~~1996)~~ * Virtual Reality classroom version of continuous performance task   **VR-CPT administrated first.**  **2. Other evaluations:**   * The Simulator Sickness Questionnaire (SSQ; Kennedy, Lane, Berbaum, & Lilienthal, 1993) * Behavior Assessment System for Children (BASC, Reynolds & Kamphaus, 1998). | Sample size: 1  Use of control groups:1  Follow-up measures: 0  Ecologically valid outcomes:1  **Total : 3/4** |
| Bioulac et al., 2012 | Population: N=36   * Clinical: 20 ADHD (boys) * TD: 16   Age:   1. to 10 years. | **1.Assessment related to study’s inclusion criteria:**   * Conners parents rating scale (CPRS)Child Behavior Check List   **2.Assessment related to study’s principal goal (assessment of attention):**   * Virtual Classroom (VC) * Continuous Performance Test (CPT II).  1. **Other measures**:  * State Trait Inventory Anxiety (STAI) * A 22-item cybersickness scale   Virtual Reality Classroom. | Sample size: 1  Use of control groups: 1  Follow-up measures:0  Ecologically valid outcomes:1  **Total: 3/4** |
| Grynszpan et al., 2012 | Population: N= 28 (final 27 as one ASD participant was excluded).   * Clinical: ASD n= 13   (1 female - 12 males)  Age: 13 to 31years   * TD: n= 14   (7 female - 7 males)  Age:13 to 31years. | 1.**Assessment related to study’s inclusion criteria:**   * Autism Diagnostic Interview (ADI) (Le Couteur et al. 1989) * Childhood Autism Rating Scale (CARS) (Schopler et al. 1980). * Raven’s Progressive Matrices (Raven and Court 1986) * Wechsler Adult Intelligence Scale, 3rd edition.   Assessment  2. Assessment related to study’s purpose   * Task VR- eye-tracking. | Sample size: 0  Use of control groups: 1  Follow-up measures:0  Ecologically valid outcomes:0  Total: 1/4 |
| Gutiérrez-Maldonado et al., 2009 | Population: N= 20   * *Clinical: ADHD=* 10 experimental group (7 males, 3 females). Experimental group: 9 diagnosed with ADHD combined type. 1 diagnosed with ADHD predominantly inattentive type. * *TD* = 10 control group (6 females, 4 males).   Age: 6 to 11 years. | **VR- Assessment (VR-Classroom**):   * 10 min * Four conditions: auditory CPT without distractors, auditory CPT with distractors, visual CPT without distractors, and visual CPT with distractors.   1. Assessment **related to study’s inclusion criteria:**   * EDAH test for TD participants (Farré & Narbona, 1998) * Assessment of Intelligence Quotient (IQ) for all participants. | Sample size: 0  Use of control groups: 1  Follow-up measures:0  Ecologically valid outcomes:0  Total: 1/4 |
| Jung et al., 2006 | Population: N=32   * Clinical: ASD n=12 (2 girls and 10 boys)   One child did not complete the procedure.  Age: 5 to 6 years   * TD: n *20*   Age: 5 to 6 years. | 1. **Assessment related to study’s inclusion criteria:**   * Social maturity scale (SMS) ASD participants * Iowa Social Competence Scales: Preschool form for TD participants * Symbol test from the intelligence quotient test (WISC) for TD participants. * **VR task for assessment** and training (10 sessions) has three components Visuomotor Coordination Ability Assessment (different reinforcement by level. Two reinforcement types: auditory (1 of 8) and visual (1 of 10) *Sensory Integration Therapy* * *Social Skills Training.*   **2. Assessment related to training:**   * Measures during the training sessions: * reaction time * Accuracy   The distance the stick was moved. | Sample size: 1  Use of control groups: 1  Follow-up measures: 0  Ecologically valid outcomes:0  Total : 2/4 |
| Kim et al., 2015 | Population: N=42   * Clinical: ASD n = 19 (13 males and 6 females)   Age = 11 years 1 month, SD = 2.5   * Group control TD n = 23   (16 males and 7 females, Age: 11 years 5 months, SD = 2.3  Age range for both groups: 8 to 16 years. | 1. **Assessment related to study’s inclusion criteria:**   * High Functioning Autism Spectrum Screening Questionnaire (ASSQ; Ehlers et al. 1999; Posserud et al. 2006) * the Social Communication Questionnaire (SCQ, Berument et al. 1999, Corsello et al. 2007) * Social Responsiveness Scale (SRS, Constantino 2004).   Assessment related to study’s purpose.   * **Virtual-reality assessment**: * Virtual-reality emotion sensitivity test (V-REST; Kim et al. 2010).   **2. Other measures:**   * Child version of the Reading the Mind in the Eyes (RME) task (Baron-Cohen et al. 2001). * Wechsler Abbreviated Scale of Intelligence (WASI) * Manifest Anxiety Scale for Children (MASC, March et al. 1997). * Behavior Assessment System for Children—2 (BASC-II; Reynolds and Kamphaus 2004). | Sample size: 1  Use of control groups: 1  Follow-up measures:0  Ecologically valid outcomes: 1  **Total : 3/4** |
| Muhlberger et al., 2016 | Population: N= 128   * Clinical ADHD: 94 * *n*=26 methylphenidate * *n*=68 unmedicated      * TD: N=34   Age:  TD: 12 years 17 (1.55)   * ADHD unmedicated: 11.43 (1.87) ADHD medicated: 11.89 (1.93). | **Assessment in VR**:   * VRC environment (Virtual Reality Classroom, Version 1.0 [Rizzo et al., 2006; Rizzo et al., 2004; Rizzo et al., 2000]) VRC-CPT * Variables Measured: * Omission errors * Commission errors. * Reaction time * Reaction time variability   1. **Assessment related to study’s inclusion criteria:**   * Kaufmann Assessment Battery for Children (K-ABC) * The Culture Fair Intelligence Test   (CFT-1)   * The Hamburg-Wechsler-Intellligence-Test für Kinder [for children].   2. **Assessment related to study’s purpose:**   * Impulsivity Venturesomeness Empathy Questionnaire (IVE) * Child Behavior Checklist for Ages 4 to 18 (CBCL/4-18) * Fremdbeurteilungsbogen für Hyperkinetische Störungen [external scoring sheet for hyperkinetic syndromes]; FBB-HKS | Sample size: 1  Use of control groups: 1  Follow-up measures:0  Ecologically valid outcomes: 0  Total:2/4 |
| Mundy et al., 2016 | Population: N: 82  Age: 9 to 13 years   * Clinical: * ASD: N: =32   Age: 11.4 years (2.1)   * ADHD: N= 27   Age: 12.2 years (2.3)   * TD: N = 23   Age: 11.8 years | **VR assessment:**  Basic Social Cognition Virtual reality paradigm (Kim and Mundy, 2012)   * Initiating joint attention (IJA) * Responding to joint attention (RJA) condition   1. **Assessment related to study’s inclusion criteria:**   * Social Communication Questionnaire (SCQ, Berument et al. 1999) * Autism Spectrum Symptom Questionnaire (ASSQ, Ehlers et al.   1999)   * Conner-3 (Conners   2010)  2. **Assessment related to study’s purpose:**   * Wide Range Assessment of Memory and Learning (WRAML2, Sheslow and Adams 2003). | Sample size: 1  Use of control groups: 1  Follow-up measures:0  Ecologically valid outcomes:0  Total: 2/4 |
| Negut et al., 2017 | Population: N=75 (45 males and 30 females)  Age :7 to 13 years   * Clinical: ADHD=33   Age: 10.24 years   * TD: N=42   Age: 8.9 years  Two experimental assessment conditions:   * VC * Traditional CPT). | **Assessment**: 2 conditions   * Traditional assessment: continuous performance test (CPT) * ClinicaVR: Classroom-CPT (VC) * Variables measured in both conditions: * Total correct responses * Errors of commission * Errors of omission * Mean reaction time * Testing session lasted for approximately two hours.   1. **Assessment related to study’s inclusion criteria:**   * Romanian form of RavenStandard Progressive Matrices Plus (Dobrean, Raven, Comşa, Rusu, & Balázsi, 2008; Domuţa, Balázsi, Porumb, Rusu, & Comşa, 2003)   **2. Assessment related to study’s purpose:**   * Digit Span and Letter Number Sequencing subtests, Coding and Symbol Search subtests Wechsler Intelligence Scale for Children – Fourth Edition (WISC-IV; Wechsler, 2003) * d2 Test of attention (Brickenkamp & Zillmer, 1998)   3**. Other measures:**   * Simulator Sickness Questionnaire (SSQ; Kennedy, Lane, Berbaum, & Lilienthal, 1993) * Cognitive Absorption Scale (CAS; Agarwal & Karahanna, 2000). | Sample size: 1  Use of control groups: 1  Follow-up measures:0  Ecologically valid outcomes: 1  **Total: 3/4** |
| Nolin et al., 2016 | Population: N=102  (53 girls and 49 boys) Participants receiving a regular school program.  Age range 7 to 16 years. | **VR-assessment**:   * ClinicaVR: Classroom-CPT * Variables measured: * Correct responses * Commissions * Right-left, up-down and tilt head movements.   1**. Assessment related to study’s inclusion criteria:**   * Developmental and general information questionnaire   2. **Assessment related to study’s purpose**   * The VIGIL-CPT   3. **Other measures**:   * Realistic subscale of the Presence Questionnaire- French adapted version * The Simulator Sickness Questionnaire - French adapted version | Sample size: 1  Use of control groups: 0  Follow-up measures:0  Ecologically valid outcomes: 1  Total: 2/4 |
| Parsons et al. 2007 | Population: N= 20  Age: 8 to 12 years   * Clinical: ADHD= 10 experimental group (males)   Age: 10.6 years   * TD: N = 10 control (males)   Age: 10.2 years . | **VR assessment:**   * VR Continuous Performance Test (CPT) * Duration: 30 min (three 10-min conditions followed the 1-min hit command phase). * Variables measured: * Reaction time * Omission * Commission * Body mouvement.   1. **Assessment related to study’s inclusion criteria:**   * Full neuropsychological battery of   Tests   * Classroom behavioral ratings * Flatscreen computer delivered CPT * Assessment of ADHD symptoms: * The SWAN Behavior Checklist (Swanson et al., No Date) * Conners’ CPT II (Conners, 2000)   2. **Assessment related to study’s** **purpose:**   * Neuropsychological measures: * The Stroop (Golden, 1978) * Trail Making tests (Reitan, 1971, 1992; Reitan & Wolfson, 2004) * Visual Attention, Design Fluency & Verbal Fluency from NEPSY (Bleckley et al., 2003). * Digit Span, Coding, Arithmetic, and Vocabulary from WISC-III (Wechsler, 1991) * Judgment of Line Orientation (Benton et al., 1983).   **3. Other measures:**   * Sickness Questionnaire (Kennedy et al., 1992; SSQ). | Sample size: 0  Use of control groups: 1  Follow-up measures:0  Ecologically valid outcomes:1  Total: 2/4 |
| Pollak et al., 2010 | Population: N=27   * Clinical: ADHD=27 (16 boys and 11 girls)   Age: 11 to 17 years. | **Assessment**:   * participants receive all 3 evaluations): * VR-CPT classroom (VR-CPT): 10 minutes * no VR-CPT: same CPT displayed on a standard computer monitor. * Test of Variables of Attention (TOVA CPT). * Variables measured: * Response time * Response time variability * Omissions (not responding to a target) * Commissions (responding to a nontarget).   1. **Assessment related to study’s inclusion criteria:**   * ADHD rating scale (ADHD-RS)   2. **Other measures:**   * Subjective feedback questionnaire (SFQ). | Sample size: 0  Use of control groups:0  Follow-up measures:0  Ecologically valid outcomes: 1  Total: 1/4 |
| Rizzo et al., 2000 | Population: N= 30  Age: 8 to 12 years   * Clinical: ADHD= 15 * TD=15 (**males).** | **VR assessment:**   * Session: approximately 30 minutes. * Variables measured: * Performance measures: reaction time and response variability will * Recording of measures, while “head turning” and gross motor movement. | Sample size: 1  Use of control groups: 1  Follow-up measures:0  Ecologically valid outcomes:0  Total: 2/4 |
| Rodríguez et al., 2018 | Population: N= 238 (241 boys and 97 girls)  Age: 6 to 16 years old (*M* = 10.84, *SD* = 3.01)   * Clinical: ADHD= 237 * 31.95% inattentive presentation * 15.38% impulsive- hyperactive presentation * 22.78% combined presentation * TD= 101   2 experimental conditions:   * Assessment with TOVA (traditional CPT): n= 172 (67.40% boys and 32.60% girls)   Age: m= 10.55 years   * Assessment with Aula Nesplora (VR-CPT): n= 166 (75.30% boys and 41% girls)   Age: m= 11.10. | **Assessment:**   * **2 conditions** * **VR CPT:** Aula Nesplora * **Traditional CPT: TOVA**   **1. Assessment related to inclusion criteria:**   * ADHD : EDAH (Farré & Narbona, 2001) * IQ: Wechsler Intelligence Scale for Children-IV (WISC-IV) * Anxiety, depression, etc. for control group: (DISC-IV; Shaffer, Fisher, Lucas, Dulcan, & Schwab-Stone, 2000). | Sample size: 1  Use of control groups: 1  Follow-up measures:0  Ecologically valid outcomes:1  **Total:3/4** |
| Wang et al., 2016 | Population: N= 11   * Clinical: ASD= 11   Age: 11 to 14 years | **VR assessment:**   * Duration of assessment:   iSocial: 22-24 h of online curriculum, divided over five units. In each unit there are 30 to 62 minutes of Naturalistic Practice (NP) activities  NP activities can last from 10 to 33 min.   * **VR task**:  1. Facial expression Scenarios 20 min   2 Share Out 10 min  3 Lost at sea: take items 25 min  4 Lost at sea: go to island 25 min  5 Sell it! 10 min  6 Restaurant buffet I 33 min  7 Restaurant buffet II 10 min  8 Emotion status activity 12 min  9 Emotional role play 25 min  10 Role play planning and taping 25 min  11 Watch and rate role plays 12 min  12 Plan Quest activity 10 min  13 Quest activity  Variables measured:  1. **Assessment related to study’s inclusion criteria:**   * Autism Diagnostic Interview Revised (ADI-R) (Rutter, Le Couteur, & Lord, 2003) * Autism Diagnostic Observation Schedule (ADOS) (Lord, Rutter,   DiLavore, & Risi, 2002).   * IQ of 75 or above (Authors do not specify how it was evaluated). | Sample size: 0  Use of control groups:0  Follow-up measures:0  Ecologically valid outcomes:0  Total : 0/4 |
| Yeh et al., 2012 | Population: N= 100  Age: 7 to 13 years   * Clinical: ADHD= 50 (experimental group) * TD= 50 (control group). | **VR assessment**:   * Virtual Reality Classroom scenario:   listening test, CPT test, executive test, and visual memory test   * Variables measured: * Correct rate * Error rate * Response time * Total time   1. **Assessment related to study’s inclusion criteria:**   * Diagnostic Rating Scale (DRS)   Other measures   * Subjective feedback questionnaire (SFQ). | Sample size: 1  Use of control groups: 1  Follow-up measures:0  Ecologically valid outcomes: 0  Total 2/4 |

Supplementary Table 4: Presentation of EF or TOM training studies’ quality (N=56)

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| --- | --- | --- | --- |
| **Authors** | **Research design: Clinical (ASD, ADHD) and Typical Development (TD) population/ sampling / Age** | **Procedure: Assessment (Duration, VR or non-VR task, neuropsychological tests)**  **Training (Duration, VR or non-VR training, Number of sessions, Type of Feedback)** | **Evaluation study quality** |
| Abirached et al., 2011 | Population: N=9 (7 males and 2 females)  Age: 4 to 11 years   * Clinical: n=9 ASD. | VR training: LIFEisGAME   * 4 game modes.  1. Recognize the expression. 2. Build a face. 3. Become your avatar. 4. Live a story. | Sample size: 0  Use of control groups:0  Randomization:0  Follow-up measures:0  Ecologically valid outcomes:0  Total : 0/5 |
| Amaral et al.,2017 | Population: N= 17   * Clinical: 4 experimental-ASD group * TD: 13 control group (7 males and 6 females)   Age:   * ASD: 15 to 22 years * TD: 21 to 26 years. | **Training in an immersive virtual environment**   1. **AEEG data acquisition : G.** Mobilab+ , g.Nautilus, V-Amp 2. . **Other valuation related to inclusion criteria:**  * ADI-R * ADOS. | Sample size: 0  Use of control groups:1  Randomization:0  Follow-up measures:0  Ecologically valid outcomes:0  Total :1/5 |
| Bauminger et al., 2007 | Population: N=6   * Clinical: HFA/ASD (three dyads)   Age: 9 to 11 years. | **VR Training duration and number of sessions**:   * 10 sessions, 3-4 times per week for 3 weeks. * Each session lasts 20 minutes. * Session 1: free play, no intervention * Sessions 2-4: shared activities: 1. shared choice, 2. shared planning, 3. shared implementation * Sessions 5-6: help and encouragement * Sessions 7-8: persuasion and negotiation.  1. **Assessment related to training:**  * Behavioral checklist of positive (e.g., use of "small talk") and negative (e.g., avoidance) social interactions * autistic behaviors (e.g., topic perseveration) * Analysis of language usage in the interactions and in the narrations.   2. **Assessment before and after the training procedure**:   * Low-tech version of   the Story Table interface   * Marble Works (to test if possible effects are transferred to other tasks). | Sample size: 0  Use of control groups:0  Randomization:0  Follow-up measures: 0  Ecologically valid outcomes: 0  Total: 0/5 |
| Bauminger-Zviely et al., 2013 | Population: N= 22  Clinical: ASD = 22 (11 pairs,18 males and 4 females)  Age: range 9.83 years. | **Virtual Reality Training**:   * 12 lessons (45-min each) * 2 computer programs (“Join-In” targeting collaboration during 6 sessions and “No-Problem” targeting social conversation in 6 sessions) * Type of feedback: Role-playing technique, feedback, and reinforcement.   **1. Assessment related to study’s inclusion criteria:**   * Autism Diagnostic Observation Schedule (ADOS; Lord et al., 2000)   Social Communication Questionnaire (SCQ; Rutter et al., 2003)   * Wechsler Intelligence Scale for Children (WISC-IV; Wechsler, 2004), Peabody Picture Vocabulary Test (PPVT; Dunn and Dunn, 1997)  1. **Assessment related to training :**  * **Social cognition measures** * Problem-Solving Measure * Concept clarification: cooperation and social conversation * Social cognition—non-direct measures * ToM: Strange Story measure. * Overt social engagement: observation on collaboration and social conversation * Companionship measure—the drawing task (Bauminger, 2007). | Sample size: 1  Use of control groups:0  Randomization:0  Follow-up measures:0  Ecologically valid outcomes:1  Total: 2/5 |
| Beaumont et al., 2008 | Population: N = 49   * Clinical: ASD * Intervention group ASD (n = 26) * Group control ASD (n = 23)   Age: 7½ to 11 years. | **VR Training:**   * Four components: group social skills training, parent training, teacher handouts and a computer game (Junior detective computer game targeting emotion recognition, emotion regulation and social interaction) * Sessions: 7 * Follow up: 6 weeks and 5 months.   **1. Assessment related to study’s inclusion criteria:**   * Childhood Asperger Syndrome Test (CAST; Scott, Baron-Cohen, Bolton, & Brayne, 2002) * Social Skills Questionnaire- teacher and parent Version (SSQ-P) * IQ = Short-form WISC-III  1. **Assessment related to training:**  * Emotion Regulation and Social Skills Questionnaire (ERSSQ) * Assessment of Perception of Emotion from Facial Expression. * Assessment of Perception of Emotion from Posture Cues. * James and the Maths Test (Attwood, 2004) Dylan is Being Teased (Attwood, 2004b). | Sample size: 1  Use of control groups: 0  Randomization: 1  Follow-up measures: 1  Ecologically valid outcomes:1  **Total: 4/5** |
| Bekele et al., 2014 | Population: N= 20  Age: 13 to 17 years   * Clinical: n= 10ASD (M = 14.7, SD = 1.1) * TD: n=10 ((TD: M = 14.6, SD = 1.2). | VR training: serious game   * Duration: 1h   **Assessment related to study’s inclusion criteria:**   * **ASD Population** * Autism Diagnostic Observation Schedule (ADOS; Lord et al. 2000). * Differential Ability Scales (DAS; Elliott 2007) * the Stanford Binet (SB; Rold 2003), or Wechsler Intelligence Scale for Children (WISC; Wechlser 2003) * Social Responsiveness Scale (SRS; Constantino and Gruber 2005) * Social Communication Ques- tionnaire—Lifetime Version (SCQ ; Rutter et al. 2003) * **TD** * Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler 1999) * Social Responsiveness Scale (SRS; Constantino and Gruber 2005) * Social Communication Ques- tionnaire—Lifetime Version (SCQ ; Rutter et al. 2003)  1. **Assessment related to training.**  * Gaze: social and non-social. 7 regions of interest (ROIs) were defined (forehead, left and right eyes, nose, mouth, other face areas and non-face regions) * Emotion recognition: accuracy, response latency, and ratings of response confidence. | Sample size: 0  Use of control groups: 1  Randomization:0  Follow-up measures:0  Ecologically valid outcomes:0  Total : 1/5 |
| Benzing et al., 2017 | Population: N= 51 (initially 66 participants)   * Clinical: ADHD   Age: 8 to 12 years (mean 10.43 years, SD= 1.37). | **VR Training:**  Duration of VR training: 8-week intervention  Number of sessions: 3 sessions per week. Total= 24 sessions  Duration of each session: 30’  Type of Feedback:  **1. Assessment related to study’s inclusion criteria:**   * Connors -3 scale (German version) * German Motor Test  1. **Assessment related to training.**  * EFs pre and post training * Simon Task (inhibition) * Flanker Task (Cognitive Flexibility) * Modified version of the color span backward task (Updating). | Sample size: 1  Use of control groups: 0  Randomization: 0  Follow-up measures: 0  Ecologically valid outcomes: 0  Total: 1/5 |
| Bernardini et al., 2014 | Population: N=29 participants, analysis of 19 participants’ results in the paper   * Clinical: 19 ASD   Age: 4 to 14 years (mean 8.5 years). | .  **VR training**:   * ECHOES (serious game)   Variables: responses and initiations of interaction with Andy (social character)   * Duration of training: 10–20 min (several times a week) over a six-week period   1.**Assessment related to inclusion criteria:**   * Social Communication Questionnaire (SCQ) * British Picture Vocabulary Scale (BPVS)   2.**Assessment of initial social communication skills**  Each child videoed during:   * free play (e.g. in the playground) * free activity in classroom * A structured group turn-taking exercise in the classroom * A structured one-on-one table-top turn-taking activity. | Sample size: 0  Use of control groups:0  Randomization: 0  Follow-up measures:0  Ecologically valid outcomes:0  Total: 0  Total:0/5 |
| Bernard-Opitz et al., 2001 | Population: N=16   * Clinical: Intervention group ASD n = 8 * TD: Group control n = 8   Age:   * ASD: 5.8 to 8.5 years (mean: 7.1) * TD: 4.0 to 4.9 years (mean: 4.56). | **VR Training**:   * Computer program: eight conflict settings (four easy and four difficult). Presentation of 4 possible solutions (2 appropriate and 2 inappropriate), and an additional option (demonstrated by a light bulb). * In the training sessions problem solutions were first explained by the trainer. Precisely, dynamic animations of the solutions were used to illustrate the explanations. * 10 training sessions interleaved with 6 probe sessions. * Feedback: reinforcement of appropriate novel ideas. On the contrary, inappropriate solutions were ignored. * Computer voice praised the child with a “happy end” to the conflict. * Additional reinforcement: selection of picture (e.g. rabbits coming out of a magician’s hat)   **1.Assessment related to study’s inclusion criteria:**   * Autism Behavior Checklist (ABC: Krug, Arick, & Almond, 1979).   Kaufman Brief Intelligence Test (K-BIT; Kaufman & Kaufman, 1990)   * British Picture Vocabulary Scale (BPVS, Dunn, Dunn, Whetton, & Pintilie, 1981).   **2.Assessment related to training:**   * Number of novel ideas produced. | Sample size: 0  Use of control groups: 1  Randomization:0  Follow-up measures:0  Ecologically valid outcomes:0  Total: 1/5 |
| Bölte et al., 2002 | Population: N =10 males   * Clinical: ASD= 10 * Intervention group ASD (n =5) * Control group ASD (n =5)   Age:16 to 40 years. | **Training:** 5 weeks (2h/week).   * VR training ~ computer-aided program to test and to train recognition of facial affect. * Feedback: * Visual feedback: “smiles?” * Audio feedback: appropriate sound.   If the answer was wrong, then feedback  sign was shown. If the subject pressed it, the right answer appeared with an explanation.  **1.Assessment related to study’s inclusion criteria**:   * German version of the Autism Diagnostic Interview-Revised Autism * German version of the Diagnostic Observation Schedule-Generic   **2.Assessment related to training:**   * Face and the eyes-test of the program * Ratings of stimuli from the International Affective Picture System (IAPS) * Cortical activity was assessed with fMRI-scans. | Sample size: 0  Use of control groups:0  Randomization: 1  Follow-up measures:0  Ecologically valid outcomes:0  Total: 1/5 |
| Bölte et al., 2006 | Population: N= 10   * Clinical: ASD=10   male adolescents and adults   * Intervention group ASD (n =5)   Age: mean 29.4 years   * Control group ASD (n =5)   Age: mean 25.8years. | **FEFA training:**   * period of 5 weeks (2 h   training a week)   * FEFA: computer-based program * Feedback: visual and acoustical reinforcement   **1.Assessment related to study’s inclusion criteria:**   * the Autism Diagnostic Interview—Revised (Lord, Rutter, & Le Couteur, 1994) * Autism Diagnostic Observation Schedule Module 3 or 4 (Lord, Rutter, DiLavore, & Risi, 2001). * Raven Standard Progressive Matrices   **2.Other measures**   * fMRI. | Sample size: 0  Use of control groups:0  Randomization:1  Follow-up measures:0  Ecologically valid outcomes:0  Total 1/5 |
| Bul et al., 2016 | Population: N= 170 children  Age 8 to 12 years   * Clinical: ADHD * group 1: 88 ADHD participants received game intervention + usual treatment for the first 10 weeks. After 10 weeks they received only usual treatment for the next 10 weeks. Analyses for 68 participants. * Group 2: 82 ADHD participants received usual treatment for the first 10 weeks. After 10 weeks they also received serious game intervention for 10 weeks. Analyses for 71 participants. | Training:   * Duration: 20-week. Participants received serious game intervention for only 10 weeks. Participants instructed to play the serious game for a maximum of 65 minutes (duration of each session), 3 times per week (total of 30 sessions). * VR training: Serious Game (Plan-It Commander), mission-guided game divided into 10 different missions and side missions. * Gratification: badges or medals in their profile, rewards (papercraft models, desktop wallpapers, and music).   **1.Assessment related to study’s inclusion criteria:**   * Kiddie Schedule for Affective Disorders and Schizophrenia-Lifetime version [K-SADS] * Disruptive Behavior Disorder Rating Scale (DBDRS) * Wechsler Intelligence Scale for Children III [WISC-III]   **2. Assessment related to training**   * Time management questionnaire * Plan/Organize of the Behavior Rating Inventory of Executive Function (BRIEF, parent version and teacher version) * Cooperation of the Social Skills Rating System (SSRS; parent version) * Secondary outcomes * subscale Working Memory of the BRIEF (parent and teacher version) * subscales Responsibility, Assertiveness, Self-Control, and Total of the SSRS (parent version and teacher version) * It’s About Time Questionnaire (IATQ ; parent version) * Self-efficacy questionnaire. | Sample size: 1  Use of control groups:0  Randomization: 1  Follow-up measures: 0  Ecologically valid outcomes:1  **Total : 3/5** |
| Bul et al., 2018. | Population: N= 143 (initially 170)  Clinical: ADHD  Age: mean 9.90 years (SD = 1.26)   * Intervention group ADHD (n =88)  1. 10-week intervention: n= 73 2. 20-week intervention: n=68   Age: mean   * Control group ADHD (n =82)  1. 10-week intervention: n= 79 2. 20-week intervention: n=71. | Training:   * Period of 20 weeks training (a) 10 weeks serious game intervention +usual treatment, b) 10 weeks usual training). * 1h session three times a week. Total sessions: 30 sessions   Serious Game: computer game “Plan-It Commander”  **1.Assessment related to study’s inclusion criteria:**   * Wechsler Intelligence Scale for Children III -WISC-III (**Intelligence quotient)** * Kiddie-Schedule for Affective Disorders and Schizophrenia-Life- time version-K-SADS (**ADHD diagnosis)** * Disruptive Behavior Disorders Rating Scale- DBDRS (s**everity of ADHD symptoms).**   **2. Assessment related to training**   * Measures administered at baseline (T0), at 10 weeks (T1) and at 10-week follow-up (T2). * Behaviour Rating Inventory of Executive Function -BRIEF (executive functions, planning/organizing skills) * Social Skills Rating System-parent version -SSRS (cooperation skills) * Management questionnaire. | Sample size: 1  Use of control groups:0  Randomization: 1  Follow-up measures: 1  Ecologically valid outcomes:1  **Total: 4/5** |
| Chen et al., 2022 | Population: N= 25  Age 6 to 12y   * Clinical= 25 ASD * CATS training group (n=12, one female)   Age: mean age =8.42, SD=1.35   * Control training group (n=13, one female)   Age: mean age =8.75, SD=1.40. | **Study procedure: Pre-test, training sessions, post-test and follow up session six months later.**  **Training:**  **2 groups: VR (CATS) and traditional training**   * Total sessions: 8 sessions, frequency once a week for 8 consecutive weeks. * Duration of each session: 50 min   **1.Assessment related to training:**   * Vineland Adaptive Behavior Scales, Chinese version (VABS). * Wisconsin Card Sorting Task (WCST; full-128- carded paper-and-pencil version). * Trail-Making Test (TMT).   **2. Assessment related to study’s inclusion criteria**:   * Raven’s Progressive Matrices * Home Observation for Measurement of the Environment (HOME; elementary version). | Sample size: 0  Use of control groups:0  Randomization: 1  Follow-up measures:0  Ecologically valid outcomes: 0  Total 1/5 |
| Cheng et al., 2010 | N= 3 (2 boys and 1 girl)  Age 8 to 11 (two 8 years old and one 11 years old)   * Clinical: 3 IDD. | **Training:**   * Baseline: collect the basic level of social-emotional competence * Participation: 3D-emotion system intervention program. * VR training: 3D-emotion system * Duration: 5-week intervention. One session per week. Each session lasts 40 minutes. * Feedback: thinking bubbles with a hint, confirmative feedback “well done” + applause animation.   1. **Assessment related to study’s inclusion criteria**:   * Wechsler Abbreviated Scale of Intelligence III   2. **Assessment related to training**:   * measurement of ‘‘social events pictures’’ (SEP). | Sample size: 0  Use of control groups:0  Randomization:0  Follow-up measures:0  Ecologically valid outcomes: 1  Total : 1/5 |
| Cheng et al., 2012 | Population: N=3   * Clinical=3 pervasive developmental disorder (boys)   Age: 9 to 12 years. | **VR Training**:   * 1 day per week for 30–40 min sessions over a 3-month period (baseline, intervention, and maintenance) * Feedback: applause and encouragement   **1.Assessment related to training**   * picture cards of joint attention (PCJA) joint attention skills scale (JASS) (baseline, intervention, and maintenance phases)   **2.Assessment related to study’s inclusion criteria:**   * Wechsler Abbreviated Scale of Intelligence III (WASI; Wechsler, 1999. | Sample size: 0  Use of control groups:0  Randomization:0  Follow-up measures: 1  Ecologically valid outcomes:0  Total:1/5 |
| Cho et al., 2002 | Population: N= 26   * Clinical: ADHD= 26 (not officially diagnosed ADHD. Participants described as having learning difficulties, being inattentive, impulsive,   hyperactive, and distracted)  3 groups:   * VR Training group (n=8)   **Age: 13 years**   * non-VR Training group (n=9)   **Age:** 15.11 years   * control group (n=9) * **Age:** 14.67 years. | **Training (VR et non VR)** :   * 8 sessions about 20 min over 2 weeks (for the VR group and the non-   VR group).   * Two cognitive training courses: Virtual Reality Comparison Training Task and Virtual Reality Sustained Attention Training Task. * Same tasks for both groups but in * VR training: use of HMD and head   tracker   * Non-VR training: use of a computer monitor.   1. Assessment/Measures related to training: number of correct answers and response time.  2. Assessment based on neuropsychological evaluation:   * Continuous performance task (CPT) before and after training sessions. | Sample size: 0  Use of control groups: 1  Randomization: 1  Follow-up measures: 0  Ecologically valid outcomes: 1  **Total: 3/5** |
| Cho et al., 2004 | Population: N=28 (males).   * Clinical: ADHD=28 (Participants not officially diagnosed, described as inattentive, impulsive, hyperactive, distracted and having   difficulties in learning)  3 groups:   * control group (n= 9) * VR group (n= 10) * non-VR group (n=9)   Age:14 to 18 years. | **Training:**   * Sessions of neurofeedback training over 2 weeks. * Each session: approximately 20’   Measures:  **1.Assessment related to training**   * **Continuous performance task (CPT): before and after training** * number of hits * reaction time * perceptual sensitivity * omission and commission errors * response bias   **2. Other evaluations/measures**   * EEG measurement. | Sample size: 0  Use of control groups: 1  Randomization: 1  Follow-up measures: 0  Ecologically valid outcomes: 1  **Total:3/5** |
| de Vries et al., 2015 | Population: initially N =166 applications, 132 screened, final N= 121 included  Age 8 to 12years   * Clinical: ASD in 3 conditions * Working Memory training: n=40. Analyses for 31 participants * Cognitive flexibility training: n=37. Analyses for 27 participants * non-adaptive control training “Mocking training”: n= 38. Analyses for 32 participants. | * Study’s schedule: Screening, pre-training, post- training (after six weeks), and follow up (after six more weeks). * Training: * Duration: Total of 25 sessions.6 training weeks.      * VR training: “Brain game Brian”   1**. Assessment related to study’s inclusion criteria:**   * Social Responsiveness Scale parent report (SRS : Constantino et al., 2003; Roeyers et al., 2011) * Autism Diagnostic Interview Schedule-Revised (ADI-R : De Jonge & de Bildt, 2007; Lord et al., 1994) * two subtests of the Dutch version of the Wechsler Intelligence Scale for Children (WISC-III: Kort et al., 2002; Sattler, 2001).   **2.Assessment related to training:**   * WM tasks resembling the training-task: Corsi block tapping task (Corsi-BTT: Corsi, 1972) * Cognitive flexibility task resembling the training-tasks: Gender-emotion switch task (Chapter 2: de Vries & Geurts, 2012) * WM task different from the training-tasks: the n-back task (Casey et al., 1995; Smith & Jonides, 1999). * Cognitive flexibility task different from the training-tasks: Number-gnome switch task, an adaptation of the number-switch task (Cepeda, Cepeda, & Kramer, 2000) * Inhibition: adaptation of the classical stop task (Logan, 1994) * Sustained attention: Sustained attention response task (SART: Robertson, Manly, Andrade, Baddeley, & Yiend, 1997)   Far-transfer to daily life (EF, Social behavior ADHD characteristics)   * The Behavior Rating Inventory of Executive Function (BRIEF: Gioia, Isquith, Guy, & Kenworthy, 2000; Dutch Version: Smidts & Huizinga, 2009; 75 items, 3- point Likert-scale) * The Children’s Social Behavior Questionnaire (CSBQ, Dutch version: Hartman et al., 2007; 49 items, 3-point Likert-scale) * The Dutch parent version of the Disruptive Behavior Disorders Rating Scale (DBDRS: Oosterlaan et al., 2000; Pelham et al., 1992; 42 items, 4-point Likert-scale). | Sample size: 1  Use of control groups: 0  Randomization: 1  Follow-up measures: 1  Ecologically valid outcomes:1  **Total: 4/5** |
| Didehbani et al., 2016 | Population: N= 30 (26 males, 4 females)   * Clinical: Asperger Syndrome or PDD-NOS * Experimental group (n= 30)   Age range 7 to 16 y. | **VR Training:**   * 10 VR-SCT sessions, 2 per week, 1 h each with a peer. * Each session: 3 scenarios * Each one lasting about 10 min. 5 min feedback/ discussion from the “coach” clinician.   **1.Assessment related to study’s inclusion criteria**:   * Autism Diagnostic Observation Schedule (ADOS; Lord, Rutter, DiLavore, & Risi, 2002) * Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999)   **2.Assessment related to training pre-test and post-test (within two weeks of completion of the intervention)**   * NEPSY second edition-facial affect recognition (NEPSY-II AR; Korkman, Kirk, & Kemp, 2007) * Triangles, also known as the Social Attribution Task (Abell, Happe & Frith, 2000) * The Developmental Neuropsychological Assessment Second Edition (NEPSY-II)-Auditory Attention and Response Set (Korkman et al., 2007). | Sample size: 1  Use of control groups: 0  Randomization:0  Follow-up measures: 0  Ecologically valid outcomes:1  Total: 2/5 |
| Dovis et al., 2015 | Population: ADHD N= (89)  Age range: 8 to 12y   * Full-active condition (n=31)   Age: 10.6 (SD= 1.4)   * Partially Active (n= 28)   Age: 10.3 (SD= 1.3)   * Placebo (n=\_30)   Age: 10.5 (SD= 1.3). | **VR training:**   * Braingame “Brian” (BGB): computerized, home-based EF training. * Number of sessions: 25 * Duration of each session: 35-50’   **1.Assessment related to study’s inclusion criteria**:   * Disruptive Behavior Disorder Rating Scale (DBDRS) * Diagnostic Interview Schedule for Children, parent version (PDISC-IV) * Dutch Wechsler Intelligence Scale for Children (WISC-III|)   **2. Assessment related to training**   * Stop task: stop signal reaction time (SSRT]). * Stroop: The Stroop Color and Word Test * Corsi Block Tapping Task (CBTT) * Digit span: the Digit-span subtest from the WISC-III test battery. * Trail Making Test (TMT): of the Delis-Kaplan Executive Function System (D-KEFS) * Raven coloured progressive matrices. * Behavior Rating Inventory of Executive Function questionnaire (BRIEF). * Sensitivity to Punishment and Sensitivity to Reward Questionnaire for children (SPSRQ-C). * Home Situations Questionnaire (HSQ). | Sample size: 1  Use of control groups: 0  Randomization: 1  Follow-up measures:0  Ecologically valid outcomes: 1  **Total:3/5** |
| Escobedo et al., 2012 | Population: N=12   * Clinical: ASD * TD: 9   Age: 8 to 11 y. | **Training in three stages:**   * pre-deployment (3 weeks): Standard Social Compass * deployment (3 weeks): use of MOSOCO during the Social Compass and breaks * post-deployment (1 week): no lessons, system not available   **1. Assessment related to training**   * videos of childrens’ interaction * Semi-structured interviews   What was measured?   * Time spent in interactions * Number of social missteps committed. * Average time in a sustained interaction, social misstep, and topic conversation. | Sample size: 0  Use of control groups: 1  Randomization:0  Follow-up measures:0  Ecologically valid outcomes:0  Total: 1/5 |
| Faja et al., 2007 | Population: N=10   * Clinical: ASD=10 * Training group (n= 5) * control group (n= 5)   Age :12 to 32 y. | **Training:**   * 8 training sessions during a 3-week period. * Session: 30 minutes to 1 h. * *Explicit rule-based instruction* emphasizing configural processing of faces * Post-test within a month   1.**Assessment related to study’s inclusion criteria**:   * Autism Diagnostic Interview–Revised (ADI–R) * Autism Diagnostic Observation Schedule (ADOS) * Abbreviated version of the Wechsler Intelligence Scale for Children–Third Edition (WISC–III) or the Wechsler Adult Intelligence Scale–Third Edition (WAIS–III).   **2.Assessment related to training**   * Standardized measures: * Long form of the Benton Test of Facial Recognition * Faces subtests of Wechsler Memory Scale–Third Edition (WMS–III) or Children’s Memory Scale. * Self-report of face-processing ability * Experimental measures -materials presented on laptop. Face stimuli (black-and-white photos). The faces used in each experimental condition differed from those used in the training. | Sample size: 0  Use of control groups: 0  Randomization: 1  Follow-up measures: 1  Ecologically valid outcomes:1  **Total: 3/5** |
| Fernandes et al., 2011 | Population in pilot study: N=2 (males)  Age: NA   * Clinical: ASD=2. | VR training:   * LIFEisGAME: 4 modes  1. Recognize the expression 2. Build a Face. This mode was used in the pilot study. 3. Become your avatar 4. Live the Story‖  * Number of sessions: 2 -3 Duration: NA * Assessment: NA. | Sample size: 0  Use of control groups:0  Randomization:0  Follow-up measures:0  Ecologically valid outcomes:0  Total: 0/5 |
| Fletcher-Watson et al., 2016 | Population: N= 54  Age:   * Clinical: ASD * Intervention training group: n=27 (21 males, 6 females)   Age: mean = 49.30 (SD=10.9)   * Control group: n=27 (22 males, (females)   Age: mean =49.96 (SD=13.2). | **1). Assessment related to study’s inclusion criteria**:   * Autism Diagnostic Observation Schedule (ADOS) * *Mullen Scales of Early Learning (MSEL).* * *Brief observation of social communication change (BOSCC)* * *MacArthur Communicative Development Inventory – words and gestures (MCDI)* * *Scripted interview including Communication and Symbolic Behaviour Scales – Developmental Profile and Gaming Experience.*   **2. Assessment related to training**   * attending to people * following social cues. | Sample size: 1  Use of control groups: 1  Randomization:0  Follow-up measures:0  Ecologically valid outcomes:0  Total : 2/5 |
| Frolli et al., 2022 | Population: N= 60   * Clinical: ASD=60 * VR Training group n= 30 (25 males, 5 females)   Age: mean age of 9.3 (SD 0.63)   * Traditional Training group n=30 (26 males, 4 females)   Age: mean age of 9.4 (SD 0.49). | Two types of raining:   * VR: 3D projection of two sequences of scenes.   Duration: 3 months, 3 times per week. N= 36 sessions  **Assessment related to study’s inclusion criteria**:   * Wechsler Intelligence Scale for Children (WISC-IV) * Autism Diagnostic Observation Schedule 2 (ADOS 2-Module 3) * the diagnostic interview for the evaluation of psychopathological disorders in children and adolescents (K-SADS-PL DSM-5) * scale for the evaluation of socio-economic status (SES). | Sample size: 1  Use of control groups:0  Randomization: 1  Follow-up measures:0  Ecologically valid outcomes:0  Total: 2/5 |
| Gordon et al., 2014 | Population: N= 34   * Clinical: ASD= 30 final 17 participants   Age: 6–18 years (M = 10.76, SD = 3.59).   * TD= 17   Age: 6-18 (M = 10.94, SD = 2.79). | VR training:   * ‘FaceMaze’ in which the Computer Expression Recognition Toolbox (CERT) is implemented. * Duration of training: NA. * Sessions: NA * Feedback: CERT provides the player with real time feedback (‘‘expression meter’’).   1**.Assessment related to study’s inclusion criteria**   * Autism Diagnostic Observation Sche- dule (ADOS) * Autism Diagnostic Interview (ADI) * Kaufman Brief intelligence Test (2nd edition) (Kbit-2)   **2.Assessment related to training**   * Rating of participants ‘‘happy’’ face, ‘‘angry’’ face and ‘‘surprise’’ face before and after intervention. | Sample size: 1  Use of control groups: 1  Randomization:0  Follow-up measures:0  Ecologically valid outcomes:0  Total: 2/5 |
| Grynszpan et al., 2008 | Population: N=20   * Clinical: ASD n= 10 (males)   Age 12 years 10 months   * TD: n= 10 (2 girls and 8 boys)   Age: 9 years 7 months. | **Training (VR game)**:   * 13 sessions of which 11 training sessions * Rate: one per week. Evaluation on the first and last sessions (3-months training) * The training program with three phases: a preparatory phase (introduction of the software), a phase of mass training and a final phase (testing interface modality using facial expressions). * Mass training: different combinations of text, speech, and images. * VR training game: ‘‘What to choose?’’   1**.Assessment related to study’s inclusion criteria**   * Wechsler Intelligence Scale for Children.   **2.Assessment related to training**   * Pre- and post-evaluations: game   ‘‘Intruder’’.  3.**Other evaluations/measures:**   * Short questionnaires assessed participants’ acquaintance with computers. | Sample size: 0  Use of control groups: 1  Randomization: 0  Follow-up measures: 0  Ecologically valid outcomes: 0  Total: 2/5 |
| Herrera et al., 2008 | Population: N=2   * Clinical: ASD=2 (males)   Age: 8years 6 months and 15years 7 months. | **Training:**   * 21⁄2 months of intervention: * 28 intervention sessions (approximately three sessions per week). * Each session lasts 20–30 minutes * **VR training**: * Supermarket exploration * Functional use * Functional Play * Imaginary Play * Creative Use   1. **Assessment:**  Questionnaires for collecting information such as the play techniques used before the study.   * ToPP test: two parts, structured and free. | Sample size: 0  Use of control groups:0  Randomization:0  Follow-up measures:0  Ecologically valid outcomes: 0  Total: 0/5 |
| Hopkins et al., 2011 | Population: N=51 (final 49 as two participants were excluded).   * Clinical: ASD=49 (5 girls and 44 boys)   4 conditions:   * Low-Functioning Autism (LFA) training (N = 11) * Low-Functioning Autism (LFA) control (N = 14) * High-Functioning Autism (HFA) training (N = 13) * High-Functioning Autism (HFA) control (N = 11)   Age: 6 to 15 years. | * **Training (VR et non VR):** * Control (art Software): 12 (2 sessions per week\*6 weeks). Each session lasts approximately 10–25 min. * Experimental (FaceSay software): 12 (2 sessions per week\*6 weeks). Each session lasts approximately 10–25 min. * FaceSay software contains three different Games. * Feedback by coach avatar (eg “Good Job”) * Post-test measures: completed within 2 weeks. * 1. **Assessment related to study’s inclusion criteria:** * Evaluation: Childhood Autism Rating Scale (CARS) * Kaufman Brief Intelligence Test, Second Edition (KBIT). * **2. Assessment related to training:** * Emotion Recognition: both photographs (Unmasking the Face) and schematic drawings Benton Facial Recognition Test (Short Form) Social Skills Observation Social Skills Rating System (SSRS) * Social Skills Observation. | Sample size: 1  Use of control groups: 0  Randomization: 1  Follow-up measures: 0  Ecologically valid outcomes:1  **Total: 3/5** |
| Ip et al., 2018 | Population: N= 114\*   * Clinical: ASD N= 94 (86 boys and 8 girls)   Age range: 6 to 12 years   * Group 1 -training): 42 male - 5 female * Group 2 (control): 44 male participants - 3 female participants * \*pilot group of 20 children (to test   out the design of the scenarios). | **Training:**   * 28-session program that lasted for 14 weeks. * Training in three stages: briefing, VR-enabled training, and debriefing. * 3-4 children (similar age) participate in each session together. * **VE sessions** last 40 min: 10 min of direct exposure to the VR environment and 30 min of observation.   1. **Assessment related to study’s inclusion criteria:**   * Raven's Progressive Matrices (RPM) (Raven & Court, 1998) * Childhood Autism Spectrum Test (CAST) (Williams et al., 2005)   **2. Assessment related to training:**   * Faces Test * Eyes Test (Psychoeducational Profile, Third Edition (PEP-3) (Schopler, Lansing, Reichler, & Marcus, 2004) * Adaptive Behavior Assessment System, Second Edition (ABAS-II) | Sample size: 1  Use of control groups:0  Randomization: 1  Follow-up measures:0  Ecologically valid outcomes: 1  **Total: 3/5** |
|  |  |  |  |
| Ke et al., 2013 | Population: N=4   * Clinical: ASD (AS/HFA) N =4   Age: 9 to 10 years. | **Training (including VR program):**   * Baseline: three 1-hr sessions over 1 week. * Sessions: each participant receives 6 to 9 sessions. (Two to three sessions per task) Each session lasts approximately 60 min. * **VR program** involved three social interaction tasks: * Recognition of body gestures and   facial expressions of a virtual communication partner   * Response and maintaining interactions at a school cafeteria. * Initiation and maintaining interactions at a birthday party.   **1. Assessment related to training:**   * *Data Collection* during baseline and intervention * *Responding and maintaining interaction* * *Leading or initiating interaction* * *Non -verbal communication* * *Pre- and post-intervention measures:* * Social Skills Questionnaire Parent and Pupil Forms (SSQ; Spence, 1995) * Assessment of Perception of Emotion from Facial Expression and Posture Cues (Spence, 1995)   2.**Measures not related to training:**   * Interviews on subject satisfaction. * Participants’ and parents’ satisfaction with the VR program * Participants’ and parents’ perceptions on VR-based interaction and learning experiences. | Sample size: 0  Use of control groups:0  Randomization:0  Follow-up measures: 0  Ecologically valid outcomes:1  Total: 1/5 |
| Ke et al., 2022 | Population: N= 7 (6 males and 1 female)  Age 7 to 14   * Clinical: ASD n=7. | VR training:   * Duration: average of 20.29 hr (SD 1⁄4 1.70), over 16–31 sessions.   1.  **Measures related to training:**   * Measures in VR environment * Initiation defined as the frequency “of verbalizations that are not in direct response to a preceding question or that occur at least 5 s after a preceding verbalization and nonverbal initiation of an interaction (e.g., wave to greet a peer’s avatar)” * Interpersonal negotiation: “An indication of the recognition of a conflict between one’s and another’s perspective, a reciprocal exchange (including opinion exchanges and reciprocal communication with a balance of perspective), verbal statements of the intent to collaborate, and the development of shared goals.” * Positive self-identity expression: “Demonstration of confidence or feelings of worth (Stainback et al., 1994) by explaining one’s own perspectives and preferences, describing individual differences, and identifying commonness with others.” * Cognitive flexibility: “Switching between solutions, tasks, or perspectives based on the changing contexts or emer-gent plan or rule changes (Geurts et al., 2009). “ * Other measures * SSQ -Social Skills Questionnaire * SCQ- Social Communication Questionnaire. | Sample size: 0  Use of control groups:0  Randomization:0  Follow-up measures:0  Ecologically valid outcomes: 1  Total: 1/5 |
| Lacava et al., 2007 | Population: N=8   * ASD n=8 (2 girls and 6 boys)   Age: 8 to11 years. | **Training**:   * 10 weeks * **VR program**: Mind Reading software with six levels of difficulty, and a character assistant helping the user.   1. **Assessment related to study’s inclusion criteria:**   * *Asperger Syndrome Diagnostic Scale* (ASDS; Myles, Bock, & Simpson,2001)   **2. Assessment related to training:**   * Four instruments for emotion recognition: the first three during posttest phase, the fourth was used only in post-test) * *Cambridge Mindreading Face–Voice Battery for Children* (CAM-C; Golan & Baron-Cohen, 2006): pre and post training * *Child Feature-Based Auditory Task* (C-FAT; Golan, 2006): pre and post training * *Reading the Mind in Films Test–Children’s Version* (RMF-C; Golan, Baron-Cohen, & Golan, 2006) post training. | Sample size: 0  Use of control groups:0  Randomization:0  Follow-up measures:0  Ecologically valid outcomes: 1  Total: 1/5 |
| Lahiri et al., 2012 | Population: N=8  Age: 13 to 1   * Clinical = 8 ASD. | **VR training:**  Duration: two sessions (sessions 1 and 2), approximately 2.5 h in total. 24 stories.  1. **Assessment related to study’s inclusion criteria:**   * Peabody Picture Vocabulary Test (PPVT) * Social Responsive Scale (SRS) * Social Communication Questionnaire (SCQ) * Autism Diagnostic Observation Scheduled-Generic (ADOS-G) * Autism Diagnostic Interview-Revised (ADI-R)   **2. Assessment related to training:**   * Performance-Sensitive System (PS) * Engagement-Sensitive System (ES. | Sample size: 0  Use of control groups:0  Randomization:0  Follow-up measures:0  Ecologically valid outcomes:0  Total: 0/5 |
| Lee et al., 2001 | Population: N=20   * Clinical: ADHD=20 * N=10 ADHD experimental group (VR training) * N=10 ADHD control group (no training)   Age: *authors do not specify the age* (young boys). | **VR training:**   * 10 sessions of VR training: each session lasts 10 minutes. Control group did not receive any training.   1**. Assessment:**   * Continuous Performance Test (pre and posttest)   Variables measured:   * Response Time (RT) * Standard Deviation of RT * Variability * Errors of Commission * Errors of Omission, Response Sensitivity. | Sample size: 0  Use of control groups:0  Randomization: 1  Follow-up measures: 0  Ecologically valid outcomes:1  Total: 2/5 |
| Liu et al., 2017 | Population: N= 2   * Clinical: ASD= 2 (males)   Age: 8 and 9 years. | **Training:**   * Brain Power System * Number of sessions: A single session * Type of Feedback: Real-time visual and auditory feedback   1. **Assessment related to study’s inclusion criteria:**   * Social Communication Questionnaire   **2. Assessment related to training:**   * Aberrant behavior checklist (ABC) pretest and post-test. | Sample size: 0  Use of control groups:0  Randomization:0  Follow-up measures: 0  Ecologically valid outcomes: 0  Total: 0/5 |
| Lorenzo et al., 2016 | Population: N= 40 students (29 boys and 11 girls)  Age:7 to 12 years   * Clinical: ASD=40 * Experimental group (training in Immersive Virtual Reality Systems) ASD Ν= 20   (14 boys and 6 girls)   * Control group ASD (training with VR software) Ν= 20   (15 boys and 5 girls). | **Training**:   * 10 structured social situations/social scenarios in IVRS or VR software   Individual sessions of 35 minutes.   * Duration: October to July   four sessions per month (40 au total)   * Feedback: evaluator provides participants with models, explanations, and alternatives.   1. **Assessment related to study’s inclusion criteria:**   * Interviews with the school psycho- pedagogical services and with the student’s tutors. | Sample size: 1  Use of control groups:0  Randomization: 1  Follow-up measures:0  Ecologically valid outcomes:0  Total 2/5 |
| Mitchell et al., 2007 | Population: N=7 (4 males, 3 females). 1 participant was excluded (male). N final= 6   * Clinical: ASD   Age: 14 to 16 years. | **Training:**   * Duration**:** video measures and VE experience took place over 6 weeks, with an equal period between the 3 video measures. * **VR training number of sessions:** 2 VE sessions for everyone. * VR exposure: each session 40 (range, 30–50) minutes   1.**Assessment:**   * Wechsler Abbreviated Scale of   Intelligence (WASI; Wechsler, 1999). | Sample size: 0  Use of control groups:0  Randomization:0  Follow-up measures:0  Ecologically valid outcomes:0  Total: 0/5 |
| Moore et al., 2005 | Population: N=34   * Clinical: ASD==34   (29 boys and 5 girls)  Age: 7.8 to16 years. | **Training VR**:   * in 3 stages   1. **Assessment related to training**:   * SVE: a total of 18 questions   three types   * Questions for which there was one correct answer from three options. * Questions with one correct answer from four options * Questions with two correct answers from three options. * Feedback: thought bubble (reinforcement in the event of a correct answer and a hint in the event of an incorrect answer). | Sample size: 1  Use of control groups:0  Randomization:0  Follow-up measures:0  cologically valid outcomes:0  Total:1/5 |
| Parsons et al., 2004 | Population: N= 36   * Clinical: ASD= 12 (10 males, 2 females)   Age range 13 to 18 years   * TD: N= 24 TD\*   \*Each ASD participant was matched with two other pupils   * one matched on verbal IQ * the other matched on performance IQ. | **VR training:**   * VR program: Virtual Cafe ́ (after completing four training trials)   1**. Assessment related to study’s inclusion criteria:**   * Abbreviated Scale of Intelligence; Wechsler, 1999) * CAT; NFER   2. **Assessment related to training:**   * Behavioral Assessment of the Dysexecutive Syndrome (BADS; Wilson, Alderman, Burgess, Emslie & Evans, 1986). | Sample size: 1  Use of control groups: 1  Randomization:0  Follow-up measures:0  Ecologically valid outcomes:1  **Total : 3/5** |
| Parsons et al., 2006 | Population: N=2   * Clinical: ASD=2   Age: 14 and 17,7 years. | Study design: 8 sessions  1 session: assessment (Wechsler Abbreviated Scale of Intelligence (WASI). Duration: approximately 30–45 min.  2. sessions: VE familiarisation. Duration: 20–30 min.  3. session: Video clips. Duration: approximately 10 min.  4. session: Cafe ́ VE. Duration: Duration: 30–45 min.  5. session Bus VE. Duration: approximately 30 min.  6. session Cafe ́ and bus VE. Duration: approximately 40–50 min  7. session Video clips. Duration: approximately 10 min.  8. session: VE follow-up and informal interview: 3 months after session 7 (identical to session 6). Duration 50–60 min.  VR training:  VE: a) café – 1 session b) bus-1 session  c) café + bus- 1 session and follow up session.  Feedback (positive and negative) were provided about appropriateness of responses.  1. **Assessment related to study’s inclusion criteria:**   * Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999)   2. **Assessment related to study’s** **purpose:**   * VE familiarization * Clips * Bus VE * Café VE. | Sample size: 0  Use of control groups:0  Randomization:0  Follow-up measures: 1  Ecologically valid outcomes:0  Total 1/5 |
| Parsons, 2015 | Population: N=14   * Clinical: ASD=6   Age:10 to 13 years   * TD=8   Age: 7 to 9 years. | **VR training:**   * Duration of Training and number of sessions: three sessions (approximately 30 min per session) over the course of two weeks. * **VR training:** Block VR Challenge CVE * Three Measures: * Interactional ‘‘moves’’ between the children. * Peer–peer communication * Teacher facilitation * **Feedback and** instructions by a virtual character.   1. **Assessment related to study’s inclusion criteria and group matches:**   * Social Communication Questionnaire (SCQ ; Rutter, Bailey and Lord * BPVS-III (Dunn, Dunn, Styles and Sewell, 2009) * IQ (WASI; Wechsler, 1999).   2. **Assessment related to training:**   * Behavioral Assessment of the Dysexecutive Syndrome for Children (BADS-C; Emslie, Wilson, Burden, Nimmo-Smith, Wilson, 2003) * Standard first-order change of location task (Baron-Cohen, Leslie, Frith, 1985) second-order task (Perner and Wimmer 1985). | Sample size: 0  Use of control groups: 1  Randomization:0  Follow-up measures:0  Ecologically valid outcomes: 1  Total: 2/5 |
| Rajendran et al., 2000 | Population: N= 4   * Clinical: ASD=4 * 2 young adult males   Age: 23 years 4 months, 23 years and 2 months  2 adolescent males Age: 14 years and 9 months, 14 years and 10 months. | **VR Training**:   * 6 Bubble Dialogue sessions * Duration of training: 6 weeks, 1 session per week * Duration of each session: 1h per session.   1. **Assessment related to study’s purpose**:   * Vineland Adaptive Behavior Scales supplementary items * Wisconsin Card Sorting Test * British Picture Vocabulary Scale | Sample size: 0  Use of control groups:0  Randomization:0  Follow-up measures:0  Ecologically valid outcomes: 0  Total: 0/5 |
| Ravindran et al., 2019 | Population: N= 12 (10 males and 2 females)  Age 9 to 16 years (m 13.5)   * Clinical: n= 12 ASD. | **VR training**: Floreo VR Joint Attention Module   * Duration: 14 training sessions, conducted over a 5-week period. 1-2 VR episodes per session.   **1. Assessment related to training**   * Total number of interactions * Use of eye contact * Initiation of interactions | Sample size: 0  Use of control groups:0  Randomization:0  Follow-up measures:0  Ecologically valid outcomes:0  Total: 0/5 |
| Rice et al., 2015 | Population: N=31 (28 males)  Age: 5 - 11 years (M=7.77)   * Clinical: n= 31 ASD * Training/intervention group: n= 16 (males)   Age: M=7.68 (SD= 1.45)   * Group control: n=15 (12 males, 3 females)   Age: M=7.87 (SD= 1.60). | **VR training:**   * *FaceSay* computer program (emotion recognition, emotions, understanding of other’s perspective, social skills)   *a)* “*Amazing Gazing” game targeting eye gaze and responding to joint attention*  *b)* “*Follow the Leader” game targeting facial expressions of emotions in avatars.*  Group control training: *SuccessMaker®*   * Duration: NA   **1. Assessment related to inclusion:**   * WISC-III or WISC- IV   2. **Assessment related to training:**   * Affect recognition (NEPSY-II, Korkman, Kemp, and Kirk, 2007). * Theory of Mind (NEPSY-II, Korkman, Kemp, and Kirk, 2007). * Social Responsiveness Scale, Second edition (SRS-2; Constantino & Gruber, 2002) * Observation of   a) po*sitive interactions (*total number): when participant initiated and engaged in positive interactions with a peer (“direct eye contact, direct eye contact combined with a smile; a smile with no eye contact, an expression of affection delivered verbally or non-verbally, etc.”)  b) Negative interactions (total number): when participant engaged in negative interactions with a peer (“physical or verbal aggressiveness etc”). | Sample size: 1  Use of control groups:0  Randomization: 1  Follow-up measures:0  Ecologically valid outcomes: 1  **Total:3/5** |
| Serret et al., 2014 | Population: N=36 final 33   * Clinical: LFA. | VR training:   * JeStiMulE game: 6 basic emotions (happiness, anger, disgust, fear, sadness, surprise), 1 complex emotion (pain) and 2 complementary expressions (neutral and ‘funny face’). Emotions are displayed on both static and animated avatars. * Duration: 2 sessions per week until participants completed JeStiMulE. 4 weeks max to achieve this goal. * Total sessions: 8 but participants could complete game earlier.   **1. Assessment related to inclusion criteria:**   * Autism Diagnostic Interview-Revised (ADI-R) * Autism Diagnostic Observation Schedule (ADOS) * Wechsler Abbreviated Scale of Intelligence (WASI) * ECOSSE (Epreuve de Compréhension Syntaxico-SEmantique) * ALOUETTE   2. **Assessment related to training pur**pose   * JeStiMulE variables * DUNN parental questionnaire. | Sample size: 1  Use of control groups:0  Randomization:0  Follow-up measures:0  Ecologically valid outcomes: 0  Total:1/5 |
| Silver et al., 2001 | Population: N = 22  Age: 10 to 18 years   * Clinical: ASD=22 * Training group ASD N = 11 * Control group ASD N = 11   Age: 12 to 18 years. | **VR training:**   * Duration of training and number of sessions (only for training group):   10 daily half-hour sessions over 2 weeks.   * **Computer program training**: * Measures/variables: number of errors made on each section. * Feedback: Correct responses are rewarded with a ‘well done’   1. **Assessment related to inclusion criteria:**   * Assessement Verbal Ability: Vocabulary Scale (BPVS: Dunn et al., 1982)   2. **Assessment related to training pur**pose  (pre- and post-test assessment)   * The Facial Expression Photographs (Spence,1980)   • Happé’s Strange Stories (Happé, 1994).  • Emotion Recognition Cartoons (8 situation-based emotions, 6 desire-based emotions and 8 belief-based emotions) from *Teaching Children with Autism to Mind-Read: A Practical Guide* (Howlin et al., 1999). | Sample size: 0  Use of control groups:0  Randomization: 1  Follow-up measures: 0  Ecologically valid outcomes: 1  Total: 2/5 |
| Skalski et al., 2021 | Population: N= 90 (finally 87 participants)  Age: 9–15 years.  3 conditions:   * Standard HEG BF (30 participants) * VR HEG BFB with distractors (initially 30 participants finally 28 participants)   VR HEG BFB without distractors (30 participants finally 29 participants). | **VR training:**   * Duration of training: 10 sessions * Frequency: once per week * Duration of each session: 30’, three 10-minute segments * conditions: standard HEG BFB; B. VR HEG BFB with distractors; C. VR HEG BFB without distractors   **1. Assessment related to inclusion criteria:**   * Raven's Colored Progressive Matrices * Quantitative EEG (QEEG) within the norm   2. Assessment related   * Selected aspects of attention. 2 assessments: 1 week before the experiment (pre) and 2-3 days after the experiment (post-test). | Sample size: 1  Use of control groups:0  Randomization: 1  Follow-up measures: 0  Ecologically valid outcomes:0  Total: 2/5 |
| Swettenham,1996 | Population: N=24   * Clinical: ASD + Down’s Syndrome * ASD group N = 8   Age: 5.6 to 15.10 years   * Down's Syndrome group N = 8   Age: 5.9 to 15.6 years   * TD N = 8 control   Age: 3.3 to 3.8 years. | **VR training:**   * Duration of training and number of sessions: 4 days training, with 2 sessions per day (total of 8 sessions) and 6 trials per session. * VR training: computerized version of the Sally-Anne false belief task.   **1. Assessment related to inclusion criteria and groups’ matches:**   * 4 false belief tasks: Dolls version of the Sally-Anne task (close transfer task) and three other false belief tasks (*Smarties Task., False Breakfast Task, and The Tom Task* - distant transfer tasks). * Verbal MA (British Picture Vocabulary Scale -BPVS, Dunn, Dunn, Whetton &Pintilie, 1982) Non-verbal MA (Leiter International Performance Scale (Arthur, 1952).   2. **Assessment related to training:**   * The transfer tasks were given in pre- and post-training period. | Sample size: 0  Use of control groups: 1  Randomization:1  Follow-up measures: 0  Ecologically valid outcomes: 0  Total:2/5 |
| Tanaka et al., 2010 | Population: N=79   * Clinical: ASD=79 children, adolescents, and young adults * Experimental group ASD N = 42 (34 males and 8 females)   Age: 10.5 years (SD = 3.8)   * control group ASD N= 37 (28 males and 9 females)   Age: 11.4 years (SD=3.7). | **VR training:**   * Duration of Training: average of 20.2 (SD = 10.3) hours of intervention average period of 19.1 (SD = 7.3) weeks. * **VR training**: Let’s Face It! Skills Battery.   1. **Assessment related to inclusion** criteria:   * Autism Diagnostic Interview – Revised (ADI-R; Rutter, Le Couteur, & Lord, 2003) * Autism Diagnostic Observation Schedule – Generic (ADOS-G; Lord, Rutter, DiLavore, & Risi, 1999) * Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999) * Wechsler Intelligence Scale for Children, 3rd edition (WISC-III; Wechsler, 1991) * Wechsler Adult Intelligence Scale, 3rd edition (WAIS-III; Wechsler, 1997), * Differential Abilities Scales (DAS; Elliott, 1990). | Sample size: 1  Use of control groups:0  Randomization: 1  Follow-up measures: 0  Ecologically valid outcomes:0  Total: 2/5 |
| Vahabzadeh et al., 2018 | Population: N=8 (7 male and 1 female participants)   * Clinical: ASD= 8 * High ADHD=4 * Low ADHD=4   Age: 11.7 to 20.5 years/ age mean (SD): 15 years (3.4) | **VR training:**   * Duration: A single session   **VR training**: Empowered Brain System (sunglasses) helps participants to recognize and direct attention toward socially salient stimuli (e.g. Human faces).   * Modules: Face2Face, Emotion Charades. * Feedback: social communication and cognitive skills coaching.   1. **Assessment related to inclusion criteria:**   * H subscale of ABC (ABC-H used also in pre and post-intervention phase) * SCQ. | Sample size: 0  Use of control groups:0  Randomization:0  Follow-up measures:0  Ecologically valid outcomes:1  Total:1/5 |
| Weerdmeester et al., 2016 | Population: N= 73 children (58 boys and 15 girls). 47 children with ADHD diagnosis and 26 children with elevated symptoms.   * Clinical Population: ADHD * Training group (ADHD): initially n= 37, final n=32 * Control group (ADHD participants without receiving dragons’ intervention: initially n= 36, final n=34   Age: 6 to 13 years (M = 9.77, SD = 1.74). | Training:   * Duration: 6 sessions over the course of 3 week. Each session lasts 15 minutes. * 2 conditions (a videogame was assigned for each group). * Intervention group: Dragon with 3 levels: ‘the forest’’ (attention and impulsivity), ‘‘the water tower’’ (hyperactivity) and ‘‘the cave” (impulsivity and motor skills) * Positive auditory feedback (‘‘You’re doing great!’’) even in case of a mistake (‘‘You’re so close, keep up the good work!’’) * Control group: ‘Angry Birds Trilogy’’   1. **Assessment related to study’s inclusion criteria:**   * ADHD VragenLijst (1 week before first session) * IQ evaluation: Wechsler Intelligence Scale for Children (WISC-II-NL) or Snijders-Oomen Nonverbal Intelligence Test (SON-R 6- 40).   **2. Assessment related to training**   * Sustained attention and impulsivity: go/no-go task (programmed in Psychology Experiment Building Language [PEBL]) * Motor skills: Movement Assessment Battery for Children (MABC-2- NL) * Gaming frequency: estimation of how many times a week participants played videogames. | Sample size: 1  Use of control groups:0  Randomization: 1  Follow-up measures:0  Ecologically valid outcomes:0  Total: 2/5 |
| Williams et al., 2012 | Population: N=55  Age: 4 to 7 years   * Clinical population: n=55 ASD participants * Intervention group n = 28 (M= 62.83, SD= 11.17, age range= 48.20–84.24)   control group: n = 27 (M= 61.93, SD= 9.91, age range= 48.10–83.09). | 1. **Assessment related to study’s inclusion criteria:**   * WPPSI-III * The Socialization Domain of the Vineland-II survey form (Sparrow, Cicchetti, & Balla, 2005)   The Autism Diagnostic Observation Schedule (ADOS, Lord et al., 2000). | Sample size: 1  Use of control groups:0  Randomization: 1  Follow-up measures: 0  Ecologically valid outcomes:0  Total : 2/5 |
| Yan et al., 2008 | Population: N = 12   * Clinical: ADHD= 12 (10 males and 2 females)   Age: 8 to 12 years. | **VR training:**   * Number of training sessions: 20 training sessions per week (5 VE games in each session). * Duration: 25-30 minutes each session. * **VR Neurofeedback.**   1. **Assessment related to training** (pre-test and after 10 sessions of training):   * Integrated visual and auditory-continuous performance test (IVA-CPT). | Sample size: 0  Use of control groups:0  Randomization:0  Follow-up measures: 0  Ecologically valid outcomes: 1  Total:1/5 |
| Yuan et al., 2018 | Population: N=94 but analysis of 72 children results (64 boys, 8 girls).  Age: 106.3 months (SD = 13.53)   * Clinical: ASD= 72 * Training group: *n* = 36 (31 boys and 5 girls)   Age- mean: 107.6 months.   * Control group/*n* = 36 (33 boys and 3 girls)   Age-mean: 104.8 months. | **VR training:**   * 6 Virtual scenarios covering real-life situations (relaxation scenario, four training scenarios and one consolidation scenario). * Duration: One-hour training session (+ briefing and debriefing sessions). * Feedback: guidance and support from the trainer   1. **Assessment related to training:**   * Affective expressions and social reciprocity from Psychoeducational Profile, Third Edition (PEP-3) Qualitative data: communication log and in-class observation log. | Sample size: 0  Use of control groups:0  Randomization: 1  Follow-up measures: 0  Ecologically valid outcomes:0  Total:1/5 |

**Supplementary Table 5: *Overview of Virtual reality´s characteristics reported in 73 studies.***

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Authors** | **Sense of presence** **and immersive experience** | | **Embodiment and User’s point of view** | | | **A. Interactive properties of the VR device**  **B. Social interaction** | | **Ecological validity of the VE** | **Participant engagement:**  How was it evaluated?  **Not Available (NA)** |
| Abirached et al. , 2011 | Visual and audio  **Low immersion**  **(serious game)** | | Embodiment/person perspective:  Virtual representation of the player’s face and map his or her facial movements and behaviors onto a virtual face.   1. Person perspective: Not exactly described in the text. Participants in the pilot study received two modules: “recognize the expression” (presentation of a sequence of random facial expressions and they must identify it) and “Build a face. “   Probably Third person perspective for the module of “Live a story”, in which a story is presented to the participant. The participant must perform the expression that is suitable to the occasion. | | | A. Serious game, Authors don’t specify how participants navigate (probably low interaction with the use of a computer mouse ).  B. Avatars seem to participate in game interactions and scenarios. | | Real life elements:   * 3D characters likable to children. | NA  Interviews with participants and parents. |
| Adams et al., 2009 | Visual and auditory information  **High immersion** | | Embodiment/person perspective: use of a sensor placed on participants’ heads. Participants observe changes in the VR classroom in response to their head movement. First-person perspective. | | | A. As mentioned before, a sensor was placed on participants’ heads. In that way, when participants moved their head, changes in the classroom were observed.  B. Presence of a virtual female teacher and other students but no social interaction between participant and the visual characters. | | Real life elements: Classroom  Scenario (virtual female teacher and other students, desks, window through which a playground, buildings, vehicles, and people can be seen). | NA  Evaluation of cybersickness (Simulator Sickness Questionnaire) **but not** participants’ engagement. |
| Amaral et al., 2017 | Visual cues  (OCULUS Rift)  **High immersion** (headset display) | | Embodiment: probably no use of avatars  First-person perspective. | | | A. NA  B. No social interaction reported, besides the instruction to look at girl’s avatar face. | | Virtual environment:  bedroom (shelves, a bed, a table, a chair, and a dresser) and objects (frames, books, lights, a printer, a radio, a ball, a door, a window, and a laptop). | NA |
| Bauminger et al., 2007 | Visual and auditory cues **Low immersion** | | Embodiment/person perspective:  no use of avatars for the participants. First- person perspective. | | | A. Participants can touch the screen to have access to elements such as the sound.  B. No social interaction reported. | | Scenarios in not real-life locations.  Use of virtual ladybugs to present the events. Ladybugs differed in size and color in and had different functions. | NA |
| Bauminger-Zviely et al., 2013 | Visual and auditory cues  **Low immersion** | | Embodiment/person perspective: use of avatars for the participants is not mentioned. First-person perspective. | | | A. Participation in cooperative dyadic activities. Participants can touch the interface (Diamond Touch surface) or use a computer mouse (Laptop computer with multimice).  B. Authors do not specify how participants communicate during the procedure. | | Join-In (social collaboration): series of social vignettes.   * Raindrops * Bridge * Save the Alien     No-Problem (social conversation): CBT role-playing technique, feedback, and reinforcement in series of social vignettes. | NA |
| Beaumont et al., 2008 | Visual and auditory cues  **Low immersion** | | Embodiment/person perspective: ‘junior detective’ is the central character of the computer game.  ~~-~~person perspective: NA | | | A. Authors do not mention how users navigated in the environment. Probably it was with a computer mouse.  B. In the example of a virtual mission presented in the paper:  participants must  1. identify how the central character is feeling  2. Decide how the character will handle a situation.  The character can   * congratulate his opponent. * yell at him * jump on a trampoline. * punch the wall. | | Junior detective computer game.  Real-life elements in level 1:  Use computer-animated but also human characters for emotion recognition.  Real-life elements in level 2:  Virtual reality missions: dealing with bullying, playing  with others and trying new things. | NA |
| Bekele et al., 2014 | Visual and auditory cues  **Low immersion**  **(**Desktop monitor + desktop remote eye tracker) | | Embodiment/person perspective: no use of avatars for participants  First-person perspective. | | | A. Interactive properties: mouse  B. No social interaction reported | | VR-based facial affect presentation created with Unity.  Real life elements:   * Avatars: 4 males and 3 females created based on the targeted age group * Emotion expression | NA |
| Benzing et al., 2017 | Visual and auditory cues  **High immersion**  **(**XBOX Kinect.) | | Embodiment/person perspective: First-person perspective. | | | A. Interactive properties:  AccelerometeR : monitor their physical activity level. Measurement of acceleration in three-dimensional space.  B. Social Interaction: no social interaction reported. | | XBOX Kinect. This device is able to project the player and his or her movements on the screen by means of a camera. | NA |
| Bernardini  et al., 2014 | **Low immersion**  (42-inch multitouch LCD display with eye-gaze tracking) | | Embodiment/person perspective: no use of avatar for the participant. Andy is not the participant’s agent/avatar.  First-person perspective. | | | A. Participants can touch the screen (e.g. the objects)  B. The objects react in unusual ways when Andy or participant touches them (transformation into other objects)    Interaction between participant and Andy. | | Environment: garden and Andy (virtual character/ social partner)   1. interactive ‘‘magic’’ objects 2. Social partner: Andy looks like a child of the participant’s age and also has a role of tutor   Andy’s capacities  1) Responding to bids for interaction  2) Initiating bids for interaction.  3) Engaging in turn taking.  Ways of interaction   1. Verbally 2. Non-verbally (gaze and gestures) 3. Combination of verbal and non-verbal behaviours. | NA |
| Bernard-Opitz et al., 2001 | Visual and auditory cues  **Low immersion**  (Computer program runs from the CD-  ROM on Windows 95 based PCs ) | | Embodiment/person perspective: no use of avatar for the participant. First-person perspective. | | | A. computer mouse  B. No social interaction reported. | | Problems differed in level of difficulty:  4 easy and 4 difficult  8 social problems:  various possible solutions + additional option (indicated by a light  bulb)   * Animations with children’s   voices.   * Static pictures of   Options.  Description by the trainer. Authors do not give examples of the static pictures. | NA |
| Bioulac et al., 2012 | Visual and audio information  **High immersion**  (Head-  mounted display -HMD) | | Embodiment/person perspective: no description of participant’s avatar. First-person perspective. | | | A. Interactive properties: Participants give their answers by pressing a mouse.  B. Social interaction:  No social interaction.  The virtual teacher gives the information to the participant. | | Virtual Classroom scenario:  1. classroom (three rows of desks, a teacher’s desk, a blackboard)  2. a female virtual teacher  3) outside the classroom (playground, buildings, vehicles etc.). | NA |
| Bölte et al.,2002 | Visual and auditory cues  **Low immersion** | | Embodiment/person perspective: First-person perspective. | | | A. Interactive properties: computer mouse.  B. No social interaction reported. | | Computer-aided program  Photographs of female and male adults from different cultures. Large spectrum of emotions. | NA |
| Bölte et al., 2006 | Visual cues and auditory cues  **Low immersion** | | Embodiment/person perspective: First-person perspective. | | | A. Interactive properties: computer mouse  B. No social interaction reported. | | FEFA: training module comprises about 500 facial affect teaching items. | NA |
| Bul et al., 2016 | Visual and auditory cues  **Low immersion** | | Embodiment/person perspective:  Avatars characteristics: captain, male/female, nickname (automatically generated). person perspective: NA | | | A. Interactive properties: It is not described how participants navigated in the environment nor B. if there was social interaction in this article.  Nevertheless, in Bul et al. 2015 it is said that participants: “navigate through the game world, talked to NPCs, collect items in the game world, communicate through predefined messages in social community”. | | Serious Game: “Plan-It Commander”, a mission-guided game environment**.** | Not measured.  But authors, before the final game, performed usability tests to examine whether children liked the game and understood how to use it and navigate within the game. |
| Bul et al., 2018 | Visual and auditory cues  **Low immersion** | | Embodiment/person perspective: Avatars characteristics: captain, male/female, nickname person perspective: NA | | | A. It is not described how participants navigated in the environment.  B. No social interaction reported. | | Serious Game: “Plan-It Commander”. | NA |
| Chen et al., 2022 | Visual and auditory cues  **Low immersion** | | Embodiment/person perspective:  no use of avatars for the participants. First-person perspective. | | | A. Different number key on the keyboard is used by the participant.  B. No social interaction reported. | | CATS, a computerized EF training program. | NA |
| Cheng et al., 2010 | Visual and auditory cues  **Low immersion**  **(l**aptop with an Intel Celeron 540 processor, 2G RAM, and windows XP SP3), | | Embodiment/person perspective: no use of avatars for the participants. First person perspective. | | | A. Interactive properties: During the experiment the button of potential answers was shown in the right side of the screen. Participants used a mouse to select.  B. No social interaction. | | 3D-emotion system (built up by PHP and MySql.)    3 stages   * Stage 1 – emotional recognition in 3D character emotions. * Stage 2 – the content of social situation situated (animated scenario) * Stage 3 – the reverse story mode   Real life elements:   * 3D character representations of four emotions * 3D simulated social situations. | NA |
| Cheng et al., 2012 | Visual, auditory, and tactile cues  **High immersion** | | Embodiment/person perspective: no description of user’s avatar. First-person perspective. | | | A. Participants use the keyboard to select their response. To control a virtual car or aircraft participants use the arrow keys. Use of data glove (to practice joint attention skills)  B. Interaction with virtual avatars. | | Social-learning situations in a playroom-scene  24 questions based on social events the environment.   * VR characteristics: * 3D animated social events * text content * instructions * voice and feedback * data glove. | NA |
| Cho et al., 2002 | Visual and audio information  **High immersion**  **(**Head mounted display and position sensor-head tracker) | | Embodiment/person perspective: Third -person perspective as participants can see themselves (self-avatar) sit- ting at the desk. | | | A. Participants can use a computer mouse to give their answers.  B. No social interaction reported.  Participants can “see” different objects in the VE” look around”. | | Virtual Reality  Comparison Training Task and Virtual Reality  Sustained Attention Training Task in classroom scenario  Real-life elements:   * Objects: whiteboard, * Avatars:   a teacher avatar, a female friend avatar. | NA |
| Cho et al., 2004 | Visual  and auditory cues  **VR group:** head-mounted display (HMD) and a head  Tracker  **High immersion**  **non-VR group:**  computer monitor with a fixed viewpoint | | Embodiment/person perspective: First-person perspective. | | | A. Interactive properties: HMD and head  Tracker  B. Social Interaction: Participant can look around in the virtual environment due to a head-mounted display (HMD). | | VR classroom scenario. | NA |
| Deriso et al., 2012 | Visual and audio  **Low immersion**  (Laptop computer + Web camera) | | Embodiment/person perspective: no use of avatar for the participant.person perspective : avatar responds to facial expression of the participant in real-time. | | | A. Interactive properties: NA  B. No social interaction reported | | System: a) CERT (Computer Expression Recognition Tool- box)  b) EMOTION MIRROR (intervention game)  c) RUBIOS (library of messages)  2 conditions:  1. it mimics you  2. you mimic it   * Real life elements: avatar responds to facial expression of the participant in real-time. | NA |
| de Vries et al., 2015 | *NA in the article.* Information in Prins et al. 2013.  Visual and audio cues  **Low immersion** | | *NA in the article*  Embodiment/person perspective: participants play the role of “Brian”~~.~~ First~~-~~person perspective: according to photos disposed in the article, participants see each scene through Brian’s eyes. | | | *NA in the article*  A. Participants: Walking around in the world (not specified how)  B. Social interaction:  Virtual characters have a problem and Brian helps them with it. | | “Brain game Brian”:  Real life elements:   * Use of real-life settings: the village, the beach etc * Characters | NA |
| Dovis et al., 2015 | *NA in the article.* Information in Prins et al. 2013.  Visual and audio cues  **Low immersion** | | *NA in the article*  Embodiment/person perspective: participants play the role of “Brian”. Firstperson perspective: according to the photos included in the article, participants see each scene through Brian’s eyes. | | | *NA in the article*  A. Participants: Walking around in the world (not specified how)  B. Social interaction:  Virtual characters have a problem and Brian helps them with it. | | “Braingame Brian”. | NA |
| Didehbani et al., 2016 | Visual and auditory cues  **Low immersion** | | Embodiment/person perspective: avatars representing the user and the clinician. Third- person perspective. | | | A. Participant’s avatar was able to do some actions (walk) and make gestures (arm or body gestures) using a standard keyboard and mouse.  B. Participant able to practice social communicationand social cognition skills.  Participant can interact with a peer and  two trained clinicians  Ex. Coach ‘s avatar provides participant with individualized verbal feedback. | | Real life elements   * Social scenario in real-life locations: * school classroom * school   lunchroom   * playground * campground * race-track * fast food   restaurant   * technology store * apartment * a coffee house * sports store * central park * Avatars were modeled to resemble each user (participant or clinician): body figure, height, eye color, hair   color, and clothes. | NA |
| Escobedo et al., 2012 | Visual cues  **Low immersion**  (use of smartphone camera to augment a real-  life social situation. Use of visual support inspired by the Social Compass curriculum ) | | Embodiment/person perspective: First-person perspective. | | | A. Augmented reality: no use of mouse, joystick, etc.  B. MOSOCO provides participants with interactive features to encourage them to make eye contact, maintain appropriate spatial boundaries, etc. | | MOSOCO: Augmented reality application     * Participants practicing social skills in real-life situations. | NA: no use of a questionnaire.  Authors mention participants’ opinion about the general use and adoption of the system. |
| Faja et al., 2007 | Visual cues  **Low immersion** | | Embodiment/person perspective: no use of avatars. First-person perspective. | | | A. Experimental conditions were presented to participants on a laptop. No information about how answers were input (mouse or keyboard).  B. No social interaction reported. | | E-Prime software  No use of scenarios.  Real-life elements   * Use of black-and-white photos for the training. | NA |
| Fernandes et al., 2011 | Visual and auditory cues  **Low immersion** | | Embodiment/person perspective: participants choose the avatar. person perspective: First | | | A. touch screen and a button  B. No social interaction reported. | | Program runs on a touchscreen computer  Real-life elements:   * Facial expressions * LIFEisGAME creates a virtual representation of the player’s face and facial movements . | NA |
| Fletcher-Watson et al., 2016 (more information in Fletcher-Watson et al. 2013) | Visual cues and auditory  **Low immersion** | | Embodiment/person perspective: First-person perspective. | | | A. participants touch the screen (use of iPad)  B. Participants can “touch” items, virtual person. | | FindMe app  Real-life elements:   * Virtual characters * Items, animals. | NA |
| Frolli et al., 2022 | Visual cues  **Low immersion** | | Embodiment/person perspective: First-person perspective. | | | A. NA  B. No social interaction. | | Real-life elements:   * Photos used and emotions presented. | NA |
| Gordon et al., 2014 | Visual cues  **Low immersion** | | Embodiment/person perspective:player navigates a pac-man-like figure. Third- person perspective. | | | A. VR interaction:   * Navigation   B. No social interaction reported. | | FaceMaze:  Users navigate as a pac-man-like figure. Participants can remove obstacles and obtain tokens by producing the appropriate happy or angry expressions.  No real-life elements. | NA |
| Grynszpan et al., 2008 | Visual cues  **Low immersion, non-immersive** | | Embodiment/person perspective:  First-person perspective. | | | A. computer mouse (user can click)  B. No social interaction reported. | | No use of scenarios.  Game: ‘‘What to choose”  Modalities-real life elements:  Human Characters’:  a 3-D image of the character’s facial expression  Cartoon Characters: similar to Human characters’ but the style was cartoonlike. | ΝΑ |
| Grynszpan et al., 2012 | Visual and auditory cues (Virtual Speaker software, Acapela Group, Inc.).  **Low immersion +** use of eye-tracking | | Embodiment/person perspective: First-person perspective. | | | A. no navigation  B. No social interaction reported. | | Real-life elements:   * Virtual   characters embedded in videos of real-life settings. Virtual characters designed with Poser Pro software (Smith Micro Software, Inc.). | NA |
| Gutiérrez-Maldonado et al., 2009 | Visual and audio information  and sensors  **High immersion** | | Embodiment/person perspective: no description provided. First-person perspective **.** | | | A. NA  B. No social interaction reported.  Instructions given by the virtual teacher. | | Virtual simulation of a classroom designed with 3D Studio, Virtools 3 Dev and Poser. | NA |
| Herrera et al., 2008 | Visual cues  **Low immersion** | | Embodiment/person perspective: First-person perspective. | | | A. Participants can navigate in the environment (touch screen, immersive VR was not available at the time)  B.  No social interaction reported.  Participants don’t interact with other virtual characters. | | Real-life environment:   * Virtual supermarket:   Use of set of videos and think bubbles. | NA |
| Hopkins et al., 2011 | Visual cues  **Low immersion** | | Embodiment/person perspective: First-person perspective . | | | A. touch screen or mouse  B. Avatars can interact with the children.  Authors claim that the interactive features of the software allow children to respond to social situations. | | FaceSay contains three different games with realistic avatars.  The tasks increase in difficulty.  Real-life elements:   1. Avatars (animated photos of real persons)   The avatars are not presented in real-life locations. | NA |
| Ip et al., 2018 | Visual and auditory cues  **High immersion**  (four-side CAVE VR system, a.k.a., half-CAVE) | | Embodiment/person perspective: **highly immersive**. First person perspective. | | | A. NA  B. Participants interact with objects and avatars in the virtual scenarios. | | Virtual learning scenario in real-life situations (6 scenarios)  Real-life elements:   * locations: e.g.bedroom, washroom (a home scene in which participants see a bedroom when the alarm clock is set off and participants have to complete some morning routines), school bus, classroom, school library, playground. | NA |
| Jung et al., 2006 | Visual, auditory, tactile cues  **High immersion**  (Pentium IV PC, projector, screen, an infrared reflector, digital camera, and tangible devices (e.g., a stick, rotation board,  trampoline). | | Embodiment/person perspective: **highly immersive**. First-person perspective. | | | A. Interactive properties: tangible devices: stick, rotation board, trampoline  B. Examples of tasks to complete:   1. Breaking virtual balloons with a real stick, in visuomotor Coordination Ability Assessment 2. Conversation between participants and the therapist in social skill training. Authors do not give many details concerning this part. | | VR–TIS: measure of human behaviors + visual feedback, as participants see the result of their actions on the screen.  For the part on Sensory Integration Therapy, images from various rides in an amusement park are shown. | NA |
| Ke et al., 2013 | Visual and auditory cues  **Low immersion** | | Embodiment/person perspective:  use of avatars for the participant  Third-person perspective. | | | A. Interactive properties: it is not specified if participants used a computer mouse to navigate in the VE.  B. Role-played scenario contextualized interaction agents.  Examples of participants’ actions in the VE   * order lunch in the school cafeteria * take a seat at a cafe table   and respond to interactions initiated by peers. | | VR-based social interaction program with three  social interaction tasks:   1. recognizing body gestures and   facial expressions of a virtual communication partner   1. responding and maintaining interactions in a school cafeteria, and (c) initiating and maintaining interactions at a birthday party.   Real-life elements:   * simulationof two social interaction settings (virtual school   and house parties). | *Subject satisfaction interviews:*     * participants and parents’ satisfaction   Participants' perceptions on VR-based interaction and learning experiences. |
| Ke et al., 2022 | Visual and auditory cues  **Low immersion**  (computer installed with the VR viewer + equipped with a mouse and a headset) | | Embodiment/person perspective:  : participants have their avatars. Person perspective: not specified. | | | A. Interactive properties: use of computer mouse  B. Social interaction reported (see training measures, e.g. Initiation of social interactions). | | 3D, desktop VR-based learning environment, created by OpenSimulator.  4 types of social interaction:  1) virtual schooling  2) social role-playing in familiar and novel tasks  3) artifact design  4) social gaming that allows or requires social interactions  Real-life elements:   * VR-simulated everyday social scenes (neighborhood, a school, amusement parks) * avatars | NA |
| Kim et al., 2015 | Visual and auditory cues  **Low immersion** | | Embodiment/person perspective: First-person perspective. | | | A. Interactive properties: use of joystick. Participants decide the distance from the avatar (how close or far to be).  B. Participants have to identify one of six basic emotions. Participants indicate their choice by  selecting from words presented on the screen. | | Virtual-Reality emotion sensitivity test:   * emotion scenario (different levels of emotional intensity).   Avatars characteristics modified to represent real life elements:   * facial expression * body   gesture (i.e., shrugs shoulders, shakes head)   * lip-synch   animation. | NA |
| Lacava et al., 2007 | Visual, auditory, tactile cues  **Low immersion** | | Embodiment/person perspective: First-person perspective | | | A. Interactive properties: not clarified if use of computer mouse.  B. Interactive games that involve skills such as guessing the emotions on a partially uncovered face, matching emotions, and assessing real-world faces. | | Emotions are  presented separately in photographs, short movie clips, and audio clips and are also demonstrated through contextual examples. | NA |
| Lahiri et al., 2012 | Visual, auditory, cues  **Low immersion**  **(**desktop VR applications) | | Embodiment/person perspective: First-person perspective. | | | A. Interactive properties: NA  Participants able to choose statements/questions during the conversations  B. Social interaction:   * conversation threads between the avatars and the participants. * Avatars narrated personal stories. | | VR-based system consisted of  a) a VR-based social communication task module  b) a real-time eye-gaze monitoring module,  c) an individualized adaptive response module  24 social tasks  Real life elements:   * social situation with real life settings * Avatars resembled the target population in age and appearance. Avatar’s voice recorded by teenagers. Avatars able to employ pointing gestures. | Exit survey:  Participants were asked:   * if they liked interacting with the system * if they had problems with the eye- tracker goggles * if they understood the stories narrated by their virtual classmate. |
| Lee et al., 2001 | Visual and audio information  **High immersion**  **(**HMD & Tracking system, EEG signal acquisition device**)** | | Embodiment/person perspective:  : **highly immersive**. First-person perspective. | | | A. Interactive properties: participants can press a number key to choose what they think to be a correct answer.  B. No social interaction reported. | | VR Biofeedback program: Not presenting a real-life situation. | NA |
| Liu et al., 2017 | Visual cues  (smart glasses)  sensors capture real-time data: movement, physiology etc  **High immersion** | | Embodiment/person perspective: First-person perspective. | | | A. Interactive properties: NA  B. Social interaction: Users can attend visually to another person’s face. | | Face Game and Emotion Game.   1. Face Game: computer vision algorithms used to detect human faces. The detected faces are “covered” with an augmented reality cartoon face.   Purpose: augmented the duration and quality of participant’s face directed gaze.  B. Emotion Game: helps participant to correctly identify the facial emotion by presenting two emoticon choices. Detection of  head movement.  Purpose: enhance emotion recognition. | Structured post intervention interview of caregivers evaluating feasibility and functionality of the proposed program.   1. Caregivers report concerning interaction with the system:  * tolerability * engagement. * Level of enjoyment * Ease of use * Level of interaction with device  1. Caregivers’ perception of participant’s emotional and behavioral change as well as theirs (e.g. stress). |
| Lorenzo et al., 2016 | Visual and auditory cues  **High immersion** and **Low immersion**   1. Immersive Virtual Reality System’s software components:  * Interface * Virtual reality generation module * Data capture module * VR software application.  1. Desktop VR | | Embodiment/person perspective:  First- person perspective. | | | A. Interactive properties: Immersive Virtual Reality Systems group: data capture module providing information about position of participant.  Desktop VR group: participant’s moods are captured with a webcam.  B. Social Interaction:  Participants can interact with the different avatars. | | Structured social situation in a specific Virtual Environment  Real life elements:   * Avatars characteristics:   Use of a computer vision system allowing avatars appearing in the virtual environment to react according to the participant's expression. | NA |
| Mitchell et al., 2007 | Visual  and auditory cues  **Low immersion**  (use of Superscape Virtual Reality  ToolkitTM. Program runs on a laptop computer using VisualiserTM software). | | Embodiment/person perspective:  : no description of participant’s avatar  First-person perspective. | | | A. Participants can use a  joystick and a mouse  B. In this single-user virtual  environment participant can initiate interactions (e.g. clicking on the person you wish to  speak to). | | Virtual environment.  Real life elements: Virtual Cafe ́ with 4 levels of increasing social complexity.  Visual and verbal feedback. | NA |
| Moore et al., 2005 | Visual and auditory cues  **Low immersion** | | Embodiment/person perspective:  First and Third-person perspective. | | | A.  B. Social Interaction: Interactions with  Avatars. | | Real-life elements:   * Avatar representations for four emotions (happy, sad, angry, and frightened).   VR program involves three stages.  In stage 1 avatar representations are sequentially displayed in isolation.  In stage 2, elicitation of the context by using a simple social scenario.  Avatars characteristics:  use simple animated sequences for avatars’ faces. | NA |
| Muhlberger et al., 2016-2020 | Visual and audio information  **High immersion**  (HMD) | | Embodiment/person perspective : First-person perspective. | | | A. Interactive properties: magnetic tracking device used to record head movements and to adapt the  field of view. To answer CPT, a clicking device was provided.  B. No social interaction reported.  Instructions given by the virtual teacher. | | Virtual Reality Classroom:  Reali-life elements:   * Objects: desks, blackboard, a window. * Avatars: a female teacher. | NA |
| Mundy et al., 2016 | Panoramic 3D displays (visual)  **High immersion**  (use of a head mounted display) | | Embodiment/person perspective: First-person perspective. | | | A. Interactive properties: HDM used to gather data.  B. Social interaction: Interacting with avatars  In responding to joint attention (RJA) condition participants are invited to make eye contact with the avatar and follow the  gaze direction.  In the initiating joint attention (IJA) condition the avatar follows participant’s gaze direction. | | Real-life elements:   * Use of 36 ‘‘familiar’’ pictures. | Not measured  NA |
| Negut et al., 2017 | Visual and audio information  **High immersion**  (head-mounted display  and headphones) | | Embodiment/person perspective: First-person perspective. | | | A. Interactive properties: mouse button  B. Social interaction: No social interaction reported.  Participants respond to the target items by pressing the mouse button. | | Virtual Classroom (CPT) /ClinicaVR: Classroom-CPT (VC)  Real life elements:   * Objects: desks, a blackboard, windows * Avatars: other pupils and a female teacher. | * Cognitive Absorption Scale (CAS; Agarwal & Karahanna, 2000)   Measures of perceived usefulness, personal innovativeness and behavioral  intention to use (Agarwal & Karahanna, 2000). |
| Nolin et al., 2016 | Visual and audio information  **High immersion**  (Head mounted display-HMD and headphones) | | Embodiment/person perspective: First-person perspective. | | | A. Interactive properties: HDM to record head movements.  B. Social Interaction: Instructions given by the virtual teacher.  No social interaction reported. | | Virtual Classroom  (Classroom-CPT)  Real-life location: objects and people in classroom. | Two questionnaires on participants’ VR experience:   * The subscale of the Presence Questionnaire. French adapted version of UQO Cyberpsychology Laboratory * The Simulator Sickness Questionnaire (Kennedy, Lane, Berbaum, & Lilienthal, 1993; French adapted version of UQO CyberpsychologyLaboratory; Bouchard, Robillard, & Renaud, 2007). |
| Parsons et al., 2004 | Visual and auditory cues  **Low immersion** | | Embodiment/person perspective: First-person perspective. | | | A. Interactive properties: joy- stick, computer mouse.  B. Social interaction: Interaction with objects, virtual characters   1. interact with objects on the screen by clicking on the mouse 2. navigation with joystick. | | Virtual Cafe´ characteristics related to a real-life situation:   * people shown in the environment (e.g., barman) * textual and verbal prompts (e.g. when participants goes close to a table -> a voice says ‘would you like to sit here?’). | NA |
| Parsons, et al., 2006 | Visual and auditory cues  **Low immersion**  (laptop with a Pentium 3 650MHz Processor, 64 MB RAM and Windows 98) | | Embodiment/person perspective: First-person perspective. | | | A. Interactive properties:   * Navigation with a USB joystick * Selection of objects   with a mouse.  B. Social Interaction: participants are required to queue appropriately. Other customers provide participant with feedback. | | VE scenarios (virtual café and virtual bus). | NA |
| Parsons et al., 2007 | Visual and audio information  **High immersion**  (head mounted display) | | Embodiment/person perspective: First-person perspective. | | | A. Interactive properties: “head turning” and arm/leg tracking devices.  B. Social Interaction: Instructions given by the virtual teacher.  No other interaction reported. | | Classroom scenario. | NA |
| Parsons, 2015 | **Low immersion**  (Block Challenge CVE runs on standard laptop. Participants use  a mouse for interaction) | | Embodiment/person perspective : First person  Perspective  (participant maintains his own perspective). | | | A. Interactive properties: mouse  B. Social Interaction : two-player Collaborative Virtual Environment  Participants interact with other people in the environment. | | Collaborative virtual reality environment (CVE). | NA |
| Pollak et al., 2010 | Visual and audio information  **High immersion** | | Embodiment/person perspective: First-person perspective. | | | A. response button  B. Social Interaction: Instructions given by the virtual teacher.  No social interaction reported. | | Classroom  Scenario. | Subjective feedback questionnaire (SFQ) consists of 8 items assessing the participant’s subjective feelings during a testing session. |
| Rajendran et al., 2000 | Visual and auditory cues  **Low immersion**  (computer application/computer-assisted simulation) | | Embodiment/person perspective: participants role play a character. Third- person perspective. | | | A. Interactive properties: Keyboard and computer mouse.  B. Social Interaction: Interaction with experimenter’s character. | | Bubble Dialogue program: role-play in a comic strip  World.  6 “theory of mind”-inspired scenarios in Virtual Environment. | NA |
| Ravindran et al. 2019 | Visual and auditory cues  **High immersion**  **(**3D immersive scene for Google Cardboard–compatible VR HMD smartphones) | | Embodiment/person perspective: First-person perspective. | | | A. Interactive properties: NA  B. Social Interaction:  Joint Attention Module. Learning cards targeting specific subskills necessary to develop appropriate joint attention behaviors. | | Floreo Joint Attention Module. | SurveyMonkey questionnaire, the “Presession Check”  SurveyMonkey questionnaire, the “Postsession Checkʺ. |
| Rice et al., 2015 | Visual and auditory cues  **Low immersion (**Computer-assisted technology**)** | | Embodiment/person perspective: First-person perspective. No use of avatars. | | | A. Interactive properties: NA  B. Social interaction: low   * attend to eye gaze * respond to joint attention * facial recognition. | | FaceSay program:   * “Amazing Gazing” game * “Band Aid Clinic” * “Follow the Leader”   Real life elements:   * Facial expresions. | NA |
| Rizzo et al. 2000 | Visual and 3D audio (Virtual Research V8 HMD, Ascension Systems head, hand, and leg tracking)  **High immersion** | | Embodiment/person perspective: First-person perspective. | | | A. Interactive properties: response button, remote mouse controller  B. Social Interaction: Instructions given by the virtual teacher.  No other social interaction reported. | | Classroom scenario  Real life elements:   * Objects: student desks, a teacher’s desk, a blackboard, Avatars: virtual teacher | NA |
| Rodríguez et al., 2018 | | Visual, audio and motor cues  **High immersion**  (3D glasses -Head Mounted Display, HMD). motion sensors and headphones. | | Embodiment/person perspective: Participant takes the perspective of a student sitting at one of the desks looking at the black- board. First- person perspective. | A. Interactive properties: Participants press a button. Sensors located in the glasses register head movements.  B. Social Interaction: No social interaction reported. | | Classroom scenario  Real life elements:   * Avatars e.g. VR teacher) * Setting (classroom). | | NA | |
| Serret et al., 2014 | | Virtual reality game (multi-sensory environment with *visual, tactile, and auditory* stimulation)  **Low immersion** | | Embodiment/person perspective: Participants choose and personalize their avatars. Third-person perspective in the training phase.  page7image7179104 | A. Interactive properties: Use of gamepad’s joystick to move the cursor horizontally in two directions.  B. Social interaction: Participants’ avatars can interact with other avatars. | | JeStiMulE individual interactive and multi-sensory computer game : 3 phases  A. calibration phase  B. learning phase  C. Training phase: 3 modules. Each module is composed of the same scenarios (26 social scenarios + 4 scenarios involving a request formula- tion).  Real life elements:   * Avatars (static or animated): * emotional faces and gestures * different identities, ages, and clothes. * Settings * City (square, garden, restaurant, theatre and shop) * Objects. | | NA | |
| Silver et al., 2001 | Visual cues, no auditory cues  **Low immersion** | | Embodiment/person perspective: First-person perspective. | | | A. Interactive properties: NA  B. No social interaction reported. | | Emotion Trainer: computer program in five sections (from emotion recognition to more complicated tasks).  Real-life elements:   * Use of digital photograph of a   Face, presentation of scenes or objects. | NA |
| Skalski et al., 2021 | 3 conditions groups  For VR: **High immersion:** HTC VIVE Cosmos Elite HMD goggles | | Embodiment/person perspective: No use of avatars for participants  First-person perspective. | | | A. Interactive properties: NA  B. Social interaction:  Authors do not specify whether any social interaction in VR environment. | | Real-life elements:   * virtual room: a computer, furniture, paintings, plants and windows. | NA |
| Swettenham, 1996 | Visual cues  **Low immersion** | | Embodiment/person perspective:  participants see the two story characters (Sally and Anne). First-person perspective. | | | A. Interactive properties: computer mouse.  B. No social interaction reported. | | *False belief computer game:*  Storyline-scenario: two versions of the Sally-Anne task  Scenarios include music, text and animation. | NA |
| Tanaka et al., 2010 | Visual and auditory cues  **Low immersion** | | Embodiment/person perspective: First-person perspective. | | | A. NA  B. No social interaction reported. | | Seven interactive computer games: Let’s Face It!  Real-life elements:   * Facial stimulus. | NA |
| Vahabzadeh et al., 2018 | Visual and audio cues  **High immersion**  (Digital Smartglasses- Augmented Virtual Reality) | | Embodiment/person perspective: First-person perspective. | | | A. System collects user’s data and delivers coaching (e.g. helps participant to pay attention to socially salient visual stimuli). Devices used: camera, microphone, touchpad, “blink” sensor, gyroscope, and accelerometer.  B. No social interaction with other avatars/participants. | | Empowered Brain System: detect human faces and facial emotions. | NA  but evaluation of participants’ tolerability of sunglasses. |
| Wang et al., 2016 | Visual and auditory cues  (**Low immersion**) | | Embodiment/person perspective: Each participant has his own avatar. Third- person perspective. | | | A. Interactive properties: NA  B. Social Interaction : Participants can interact  with peers via the avatars (verbal and nonverbal communication)  Goal-oriented activities: stimulation of discussions and negotiations   * Game-like activities: Participants can manipulate   objects and select options. | | 3D Collaborative Virtual Learning Environment  (CVLE)-iSocial:  13 Naturalistic Practice (NP) learning activities  CVLE ‘s characteristics related to real-life situations:  Virtual environment  objects in the VE   * avatar's representation. | Evaluation of:   1. embodied sense of presence (sense of avatar representation of self” and “sense of virtual objects/context) 2. embodied copresence (“sense of avatar representation of other people” and “sense of avatar proximity”)   social presence (“sense of collaborative engagement”, “sense and appraisal of others”, and “sense of one's own actions as manifest in avatar-based social interaction”).  Evaluation by Examining questions and evidence coming from observation of participant’s behavior and verbatim. |
| Weerdmeester et al., 2016. | | Visual and auditory cues  **Low immersion**  (Laptop attached to a large TV screen Xbox 360 Kinect sensor) | | Embodiment/person perspective: participant embodies a young and inattentive dragon (dragon is only seen from the back). Third- person perspective. | A. Interactive properties: NA  B. No social interaction  The avatar copies the movements of the player. | | Game based intervention: Adventurous Dreaming Highflying Dragon. | | Not measured  But authors tried to evaluate participants’ experience by asking some evaluative questions about the games :   * ‘‘How much did you like playing the game?’’ * ‘‘How difficult did you find the game?’’ * ‘‘Did you learn something from the game?’’ * ‘‘Would you like to play the game with someone else?’’. | |
| Williams et al., 2012 | Visual and auditory cues  **Low imersion** | | Embodiment/person perspective: First-person perspective. No immersion. | | | A. Interactive properties: no  B. Social Interaction: no social interaction reported. | | Transporters DVD programme: vehicles with human faces. | NA |
| Yan et al., 2008 | Visual and auditory cues (VE games)  **Low immersion** | | Embodiment/person perspective: First-person perspective. | | | A. Interactive properties: NA  B. Social Interaction: No social interaction reported. | | Brain Computer Interface (BCI) Neurofeedback (NFB)- Virtual Reality (VR) system: VE games (e.g. three spaceships). | NA |
| Yeh et al., 2012 | Visual and audio information    **High immersion**  (Use of head  mounted display-HMD, game technology and sensors) | | Embodiment/person perspective:First-person perspective. | | | A. Interactive properties:   * HMD with embedded posture identified * Alternative experiment : three computer screens and eye tracker.   B. Instructions given by the virtual teacher.  No interaction reported. | | Interactive panoramic virtual classroom scenario  Real life elements :   * Objects : desks and chairs, blackboard * Avatars :other   students, teacher. | NA |
| Yuan et al., 2018 | Visual and audio information (viewing goggles)  **High immersion** | | Embodiment/person perspective: First-person perspective. | | | A. Interactive properties : NA  B. Social Interaction : Interaction with objects and avatars. | | Four-side Cave  Automatic Virtual Environment (CAVE):  Reali-life elements :   * use of virtual   Scenarios (a relaxation scenario, four training scenarios and one consolidation scenario) covering real-life situations. | NA *but* authors evaluate participants’ tolerability of viewing goggles. |