Chapter 7
Virtual Teacher and Classroom for Assessment of Neurodevelopmental Disorders

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Abstract Differential diagnosis and treatment of neurodevelopmental disorders that impact the brain's frontostriatal system require assessments that can differentiate the overlapping symptoms. Previous research has most often relied on paper-and-pencil as well as computerized psychometric tests of executive functions. Although these approaches provide highly systematic control and delivery of performance challenges, they have also been criticized as limited in the area of ecological validity. A possible answer to the problems of ecological validity in assessment of executive functioning in HFA children is to immerse the child in a virtual classroom environment where s/he interacts with a virtual human teacher.

Keywords Autism · Attention deficit hyperactivity disorder · Frontostriatal system · Virtual reality · Virtual classroom · Virtual human · Neuropsychology · Social skills training

7.1 Introduction

Autism and attention deficit hyperactivity disorder (ADHD) are neurodevelopmental disorders that impact the brain's frontostriatal system and hinder adaptive responses to environmental situations. Since children affected by high functioning autism (HFA) and ADHD often have overlapping symptoms one pressing need is to better understand the syndrome specific pattern of attention problems, and related treatment needs, that differentiate HFA children from those affected by ADHD. Standard measures of executive functions indicate that HFA but not necessarily ADHD children have difficulty with planning and set-shifting or

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cognitive flexibility [1, 2]. Inhibitory control, however, seems to be an executive function that is relatively spared in children with autism [3]. Alternatively, although the executive deficits exhibited by those with ADHD seem to be heterogeneous in nature, their primary executive deficit may be in inhibitory control, specifically suppressing automatic processes or prepotent responses and/or maintain task instructions or representations in working memory [4]. Thus, inhibition is one area of executive functioning that may distinguish children with HFA (no deficit) from children with ADHD (deficit). However, support for this hypothesis has been equivocal.

Previous research has most often relied on paper and pencil-based psychometric tests of executive functions. Although these approaches provide highly systematic control and delivery of performance challenges, they have also been criticized as limited in the area of ecological validity [5]. By ecological validity, neuropsychologists mean the degree of relevance or similarity that a test or training system has relative to the real world, and in its value for predicting or improving daily functioning [6, 7]. Adherents of this view challenge the usefulness of constrained paper-and-pencil tests and analog tasks for addressing the complex integrated functioning that is required for successful performance in the real world. This may be especially true for testing executive function deficits in HFA children because of the social orienting hypothesis of autism. One hallmark of autism is a syndrome specific difficulty with the tendency to attend to and process social stimuli, such as faces or the direction of eye gaze [8, 9]. HFA children may display confusing commonalities with children affected by other frontostriatal developmental disorders such as ADHD. To resolve this issue there is a need to develop ecologically valid measures of social-orienting executive dysfunction in HFA children.

A possible answer to the problems of ecological validity in assessment of executive functioning in HFA children is to immerse the child in a virtual classroom environment where s/he interacts with a virtual human teacher. Research on VR has begun to support its potential for assessment and training of social skills in individuals with ASD. On the assessment side, work has been done to develop a virtual classroom that assesses executive functioning [10, 11]. These virtual environments have been found to offer significant advantages to more traditional methods of diagnosis and observation [12]. The use of virtual environments for training of social skills in individuals with ASD is increasing [13–15]. VR paradigms allow people with ASD to practice their social skills in a safe environment. As they explore the social situation the consequences for their actions (positive or negative) can be carefully controlled by the therapist [16]. Thus, the reaction of the avatars in the VE can be realistic but the therapist can determine the pace and complexity of exposure to social contexts and allow for optimal individualized practice of interaction as many times as is necessary [16]. Thus, VR intervention for children with HFA may also provide a safer environment than "real life" for realistic role playing exercises that maximize learning from mistakes while minimizing their real life consequences [17]. This type of safe role-playing in a virtual social context may be vital to the mastery and generalizability of social skills training with HFA children [18–20].

Recent work by Parsons at the University of North Texas has combined the attentional assessment found in a virtual classroom environment with virtual human technology. The idea is to place a virtual human teacher with verbal and nonverbal receptive and expressive language abilities into the virtual environment to aid in assessment of joint attention. The virtual human teacher acts as a social orienting system that comports well with the social orienting hypothesis of autism. As a result, researchers may differentiate attention deficits that exist regardless of social facilitation from those executive functions that may be alleviated by a virtual teacher. The use of a virtual teacher may be especially helpful in differentiating ADHD and HFA children because children with autism may be especially well motivated in computer-based paradigms. Children with autism have been observed to prefer the computer work relative to regular toy situations [21], to work more diligently on computer tasks [22] and to benefit more from computer enhanced than typical behavioral learning interventions [23]. Computer-based neuropsychological assessments offer a number of advantages over traditional paper-and-pencil testing: increased standardization of administration; increased accuracy of timing presentation and response latencies; ease of administration and data collection; and reliable and randomized presentation of stimuli for repeat administrations [24, 25].

The plan of this chapter will be as follows: In Sect. 1, current approaches to the differentiation of cognitive sequelae in neurodevelopmental disorders will be discussed. Section 2 will review past work using virtual environments for these populations. Next, in Sect. 3, virtual human research will be introduced. Finally, in Sect. 4, there will be a discussion of the promise and potential limitations of a virtual teacher/classroom environment for assessment and treatment of attentional deficits.

7.2 Neurodevelopmental Disorders: Differentiation of Their Cognitive Sequelae

Autism is a neurodevelopmental disorder involving impairments in social and communication skills, as well as repetitive behaviors or thought process [26]. Prevalence estimates have increased dramatically in the last twenty years such that this disorder is now recognized to afflict 1 in 88 children nationwide [27]. An aspect that may help to differentiate attentional processing between persons with ADHD and persons with HFA is the social orienting disturbance wherein children with autism display a syndrome specific difficulty with the tendency to attend to and process social stimuli, such as faces or the direction of eye gaze [8, 9]. The social orienting deficits of persons with autism may limit their capacity for social learning at home and in school and also play a role in their problematic development of social competence and social cognition [28, 29]. Recent research suggests that the social orienting impairments of autism reflect a disturbance of "social executive" functioning that involves frontal motivation, self-monitoring, volitional attention regulation. Further, deficits appear to be found in temporal/parietal systems that involve orienting and processing information about the behavior of other persons [9, 30, 31].

While there are children with autism that are higher functioning, even those that are considered HFA exhibit ongoing and significant deficits in social and communication skills, as well as problematic repetitive behaviors, and excessive focus on isolated areas of interest [32, 33]. Variability in the social and emotional status of these children is often complicated by comorbid ADHD symptoms [34, 35] and other emotional or behavioral disorders including anxiety [36, 37]. An unfortunate limitation of the current diagnostic system is that it does not allow for the combined diagnosis of ADHD with Autism [26]. As a result, there is often potential for HFA children to be misclassified as ADHD and vice versa [35, 38].

Given the overlapping symptoms commonly associated with differential diagnosis of HFA and ADHD, there is need for enhanced understanding of the syndrome specific pattern of attention problems, and related treatment needs that differentiate HFA children from children with ADHD. Both clinical groups are affected by frontal-striatal impairments of attention regulation [39, 40], which likely accounts for part of the symptom overlap, especially with respect to atypical patterns of attention regulation. Nevertheless, social orienting theory and research suggest that HFA children may be expected to display more attention problems in tasks involving social cueing than ADHD children. Standard methods for identifying and assessing social attention problems have been developed for preschool children with autism, such as joint measurement and intervention [41]. However, comparable social attention assessment and intervention methods for school age, higher functioning children have yet to be developed. The development of these methods is more difficult for older higher functioning children because social attention assessment and intervention is best conducted in controlled but ecologically valid social stimulus situations. In older higher functioning children the social stimulus complexity required for ecological validity often impedes the development of sufficiently controlled and transferable methods for social assessment and intervention methods.

Executive attention dysfunction is central to autism [42] especially the social executive demands of coordinating attention with others [9]. The latter refers to joint attention disturbance which can easily be measured in younger children in structured social interaction paradigms. Comparable standard measures are not yet available for older higher functioning children. Instead researchers have most often tried to assess attention problems in non-social executive function tasks or with non-interactive face processing measures [43–45]. The syndrome specific utility of these types of measures is debatable because other disorders such as ADHD involve impairments of attention but little is yet know about the types of attention measures which best discriminate children with HFA or ADHD. Work with non-social executive attention measures suggests that a combination of Stroop and Go-No-Go paradigms may be useful in this regard. ADHD children have difficulty in inhibition prepotent responses on a Stroop Paradigm but children with HFA have significantly less difficulty on these types of task [42]. ADHD children also make more errors of omission and commission on Go-No-Go tasks (e.g. inhibiting a response to “3” in repeated ordered sequences of 1–9) than HFA children indicating that they have more difficulty with attention maintenance and inhibition processes [2]. However, if the task is changed to inhibit responding to a number (3) in a repeated but random sequence of 1–9 numbers, HFA children display a pattern of inhibition errors comparable to ADHD children [46]. Thus ADHD and HFA children may appear similar or different with respect to attention inhibition disturbance based on stimulus presentation parameters.

In addition to Go-No-Go and Stroop methods, recent research suggests that computer-generated flanker tasks lend themselves to discriminant social attention assessment in HFA and ADHD children. In a flanker task children must respond to the direction of a central stimulus surrounded by distracting flankers and the stimuli may be non-social (e.g. arrows) or social (e.g. the direction of gaze in faces). ADHD children display poor performance and abnormal neurocognitive processing on non-social flanker tasks [47, 48]. Alternatively, HFA children display less evidence of behavioral impairment on a non-social flanker task [49, 50] but more evidence of difficult on a social-flanker task than control comparison children [50]. The observations of Dichter and Belger [50] are consistent with the social orienting hypothesis of autism and suggest that there may be a syndrome specific deleterious effect of social attention on cognitive control and executive functions in HFA children.

It is important to note that having a computer (instead of a human) provide feedback on neurocognitive tasks has yielded better inductive reasoning and cognitive flexibility performance in children with autism relative to controls [51, 52]. For example, on neuropsychological tests that assess the ability of a person to display flexibility in the face of changing schedules of reinforcement (i.e., “set-shifting”) individuals with autism have been reported to be highly perseverative compared to neurotypical controls and controls with other neurodevelopmental disorders: ADHD, language disorder, Tourette’s syndrome and dyslexia [3, 53–55]. One example of this is seen on the Wisconsin Card Sorting Task (WCST), in which subjects can be tested for mental flexibility via requirements that the participants sort cards according to one of three possible rules (color, shape, or number). There are a number of component cognitive processes that are required for successful performance on the WCST: generation of a sorting rule, holding the sorting rule in working memory, inhibition of prepotent responding, and the ability to maintain/shift set). An interesting issue is that executive function tasks like the WCST have a high degree of interpersonal interaction between the persons with autism and an experimenter. In a study by [51], individuals with autism were presented with both a standard (examiner gives a paper card to subject and gives instructions) and a computerized version of a card sorting task. Results revealed that group differences found on the standard administration were not present during the computerized administration. Here we see the potential for increased executive functioning performance by children with autism when the social interaction with an experimenter is removed from the testing situation.

7.3 Virtual Environments for Neurocognitive Assessment

One viable approach to the above mentioned problems (e.g., differentiating Autism from other neurodevelopmental disorders) is to capitalize on advances in virtual reality (VR) technology. Virtual environments can provide platforms for child social-attention assessment and intervention that is sufficiently rich in terms of ecologically validity, while also providing scientifically rigorous control, manipulation and bio-behavioral data recording options [10, 56–58]. Virtual Reality is form of human–computer interface that allows the user to "interact" with and become "immersed" in a computer-generated environment [59]. VR offers the potential to deliver systematic social interaction learning opportunities with "virtual people" in precisely controlled, dynamic three-dimensional (3D) stimulus environments [60, 61]. VR paradigms also allow for the sophisticated, objective, real-time measure of participants' behaviors (e.g. visual attention) and training outcomes, such as changes in social attention [10, 61]. Recent cost reductions in VR technologies have led to the development of more accessible, usable and clinically relevant VR applications that can be used to address a wide range of physical and cognitive ailments and conditions [62].

Another reason that virtual environment based assessments may be preferable is that while standard neuropsychological measures have been found to have adequate predictive value, their ecological validity may diminish predictions about real-world functioning. Traditional neurocognitive measures may not replicate the diverse environment in which persons with autism and other neurodevelopmental disorders live. Additionally, standard neurocognitive batteries tend to examine isolated components of neuropsychological ability, which may not accurately reflect the distinct cognitive domains found in neurodevelopmental disorders impacting frontostriatal functioning [63–66]. Although today's neuropsychological assessment procedures are widely used, neuropsychologists have been slow to adjust to the impact of technology on their profession. While there are some computer-based neuropsychological measures (see discussion above) that offer a number of advantages over the traditional paper-and-pencil testing, the ecological validity of these computer-based neuropsychological measures is less emphasized. Only a handful of neuropsychological measures have been developed with the specific intention of tapping into everyday behaviors like interacting with a teacher and peers in a virtual school setting, navigating one's community, grocery shopping, and other activities of daily living. Of those that have been developed, even fewer make use of advances in computer technology.

Virtual environment applications that focus on treatment of cognitive [62, 67] and affective disorders [68, 69], as well as assessment of component cognitive processes are now being developed and tested: attention [10, 70–72], spatial abilities [73, 74], retrospective memory [75], prospective memory [76], spatial memory [77–79] and executive functions [80–82]. The increased ecological validity of neurocognitive batteries that include assessment using virtual scenarios may aid differential diagnosis and treatment planning. Within a virtual world, it is possible to systematically present cognitive tasks targeting neuropsychological performance beyond what are currently available using traditional methods [5, 60]. Reliability of neuropsychological assessment can be enhanced in virtual worlds by better control of the perceptual environment, more consistent stimulus presentation, and more precise and accurate scoring. Virtual environments may also improve the validity of neurocognitive measurements via the increased quantification of discrete behavioral responses, allowing for the identification of more specific cognitive domains [83]. Virtual environments could allow for neurocognition to be tested in situations that are more ecologically valid. Participants can be evaluated in an environment that simulates the real world, not a contrived testing environment [84]. Further, it offers the potential to have ecologically valid computer-based neuropsychological assessments that will move beyond traditional clinic or laboratory borders.

7.4 Assessment of Neurodevelopmental Disorders Using Virtual Environments

Previous research indicates that computer based tasks may be especially appealing to children with autism and encourage future studies [18]. More importantly a small but growing literature indicates that HFA children readily accommodate to virtual environment paradigms and that these paradigms can be effectively used for both social assessment and social intervention. Parsons, Mitchell, and Leonard [18] reported a study in which 12 HFA children displayed comparable competence and enjoyment of a VR environment compared to IQ matched comparison children. The HFA children, though, had more difficulty maintaining appropriate social distances in the VR space. In a subsequent detailed study of phenomenological experience two HFA adolescents were observed to treat VR scenes meaningfully. The adolescents also reported that they enjoyed using the VR platform and provided examples of how they thought the experience could help them in the real world. Also, Trepagnier et al. [20] have described the utility of a VR paradigm for assessing social attention problems (face and eye gaze) in a small sample of HFA children. These studies attest to the feasibility and potential of VR paradigms for assessment and intervention with HFA children.

These prior studies have emulated isolated face presentations or more complex virtual café or bus stop environments [18, 20]. However, one of the most important social contexts for VR emulation with HFA children may be the classroom. HFA children often can regulate their attention well enough to do well in academic classroom requirements. Nevertheless, their inability to deal with the social attention and information demands placed on them by teachers and peers can lead to significant behavior problems that are often mistaken for ADHD, as well as anxious or dysphoric mood that undermine their adaptive skills [32]. Consequently, one optimal ecologically valid approach to diagnosis and treatment of these children may be to use VR methods to simulate classroom social-educational environments under controlled conditions.

A program of basic research by Parsons and Rizzo at the University of Southern California has been the development of a Virtual Classroom over the past several years [10, 11]. Parsons, now at the University of North Texas, has extended the research to include social facilitation of a virtual teacher and other environmental cues (including flanker tasks) to assess social attention. The aim of Parsons's research program has been to develop virtual reality applications for the study, assessment and rehabilitation of attention, cognitive and psychological sequelae of central nervous system dysfunction in children and adults affected by psychopathology or trauma [62]. The original virtual classroom used a head mounted display to present cognitive tasks that appear on a chalkboard and distracters (visual and auditory) that occur both within the virtual classroom and "outside" the classroom window and door. Thus, researchers and clinicians can provide a controlled but rich social stimulus environment where attention and other cognitive challenges can be presented to children along with the precise delivery of and control of distracting auditory and visual stimuli within the naturalistic virtual environment [10, 11]. The validity and utility of the VR classroom has been demonstrated in a study in which response to a Go-No-Go task in the virtual environment differentiated ADHD children from controls on numerous measures of attention and activity [10]. Furthermore, individual differences in virtual classroom attention performance were associated with parent reports of ADHD symptoms [10, 85].

7.5 Virtual Reality for Assessment and Treatment of Social Skills

Numerous studies now indicate that VR methods are applicable with HFA children. Indeed, they may be especially enjoyable and motivating intervention platforms for children with HFA [18]. Children with autism have been observed to prefer the computer work relative to regular toy situations [21], to work more diligently on computer tasks, and to benefit more from computer enhanced or VR intervention than typical behavioral learning interventions [23, 86]. Wallace et al. [87], have observed that many children with HFA report a sense of presence in VR environments that is comparable to that of typical children and other studies have provided preliminary support for VR based social skills training for individuals with ASD [13–15]. As they interact in the virtual social situations the consequences of their actions (positive or negative) can be carefully controlled by the therapist [16]. The realism of VR social interactions can be varied and researchers can control the pace and complexity of exposure to social contexts. This allows for a degree of individualized design with regard to the VR practice of social skills [16]. Thus, VR intervention for children with HFA provide a safer environment than “real life” in which to practice social skills exercises that maximize learning while minimizing risks of failure and negative reinforcement learning [17]. The types of safe role-playing available in virtual social encounters may be especially vital to the mastery and generalizability of learning and social skills training with HFA children [14, 18–20, 88]. Moreover, case study of VR therapy with a child with cerebral palsy suggests that virtual reality treatments may be have sufficient impact on growth and development of children to be associated with functionally adaptive cortical reorganization [89].

A further experimental technology approach to work with children with high functioning autism, includes embodied conversational agents acting as virtual teachers, peers, and tutors. Embodied Conversational Agents (ECAs) are animated virtual agents that interact with users in real-time dialogue through the recogntion and performance of both speech and gesture [90–92]. Tartaro and Cassell [93] as well as Bosseler and Massaro [94] have used virtual animated characters to elicit social skills and language learning. For example, Tartaro and Cassell used a virtual peer used to improve social interaction skills, including turn-taking and gaze behavior. After interaction with the ECA, children improved their scores on the Test of Early Language Development and displayed increased social behaviours, such as improved gaze. They argue that using a virtual human may be preferable to actual human interactions in children with high functioning autism, because virtual tutors have the patience to interact with individuals with these children. Bosseler and Massaro also used ECA tutors for children with autism. For their work, even a month after the intervention with the embodied agent, children were still using their newly acquired vocabulary in everyday situations. The results from these evaluations are very encouraging, and it is hoped that an autonomous social skills tutor aimed at children with autism will likewise lead to improved social outcomes.

7.6 Virtual Teacher/Classroom Environment for Assessment/Treatment of Attention

Thus far this chapter has reviewed some of the issues inherent in differential diagnosis of deficits in children with autism when compared to children with ADHD. The chapter has discussed the ways in which various assessment modalities (paper-and-pencil, computerized, and virtual reality) can be used for differentiating aspects of executive functioning in neurodevelopmental disorders affecting frontostriatal functioning. Of note, the virtual reality environments offer ecologically valid assessment of activities of daily living. Further, through the use of intelligent virtual agents, children with autism can be aided in their development of social skills. In this section, the goal is proffer a potentially exciting new approach to neurocognitive differential diagnosis and social skills training through an integration of ECAs into a virtual schoolroom environment. This approach moves beyond the limitations of past virtual classroom environments that had only limited experience of passive virtual characters to an approach that takes the best of the virtual classroom and merges it with a socially interactive teacher.

The social orienting deficits of persons with autism may limit their capacity for social learning at home and in school and also play a role in their problematic development of social competence and social cognition. Recent research suggests that the social orienting impairments of autism reflect a disturbance of "social executive" functioning that involves frontal motivation, self-monitoring, volitional attention regulation. Further, deficits appear to be found in temporal/parietal systems that involve orienting and processing information about the behavior of other persons. The integration of a virtual teacher into a virtual classroom environment would allow for a more dynamic assessment of both personal and joint attention. While much of the work discussed thus far has focused on an individual's regulation, control, and management of cognitive processes in isolation of others, persons with developmental disorders may have increased deficits in planning, working memory, attention, problem solving, verbal reasoning, inhibition, mental flexibility, task switching, and initiation and monitoring of actions when interacting in a social environment. Of primary interest here is the shared focus (i.e., joint attention) of two or more individuals on an object. Joint attention is achieved when an individual alerts another to an object via eye-gaze, pointing, and/or non-verbal indications. As mentioned earlier, children with autism may have deficits in skills related to joint attention: eye gaze; and identifying intention.

The current iteration of the virtual teacher and classroom includes a battery of neuropsychological measures that can be administered with or without social cues from the virtual teacher: continuous performance test (CPT); picture naming test; and a stroop test. The actual virtual environment includes rows of desks, a teacher's desk at the front, a whiteboard across the front wall, a female virtual teacher between her desk and whiteboard, and peers seated "with" the participant in the room. The virtual teacher instructs the participant to look around the room and to point and name the various objects that they observed. Following this one-minute warm-up period, the virtual teacher tells participants that they are going to "play a game". In the virtual environment, participants view a sequence of stimuli (e.g., CPT; Stroop; or pictures) that appear for brief (a couple seconds) intervals to the left and right of the teacher on the whiteboard. There is a random inter-stimulus interval between the appearance of the stimuli (e.g., CPT; Stroop; or pictures) and the sequence of appearance and disappearance of left and right stimuli is asynchronous. The virtual teacher asks participants to depress a "left" or "right" hand button when any of four target stimuli appears behind her. The virtual teacher also says: "When I look this way (virtual teacher turns left) the target pictures will appear on this side of the board;" "When I look this way (virtual teacher turns right) the target pictures will appear on this side of the board;" and "When I look this way (virtual teacher looks straight ahead) pictures can appear on either side of the board". Two blocks of pictures are presented in fifteen sets of ten pictures. Five sets of ten pictures in each block randomly occur with the teacher looking left, right or forward. Two target pictures are designated in six sets of ten pictures and three target pictures are designated in nine sets of ten pictures.

Distracters are presented across the entire presentation series. Distracters are presented for the entire period of presentation of stimuli. Nine social distracters (e.g., people moving by outside the classroom) and nine nonsocial distracters (e.g., cars moving by outside the window) are presented across the sets of stimuli. Social and non-social distracters occur with the teacher looking to the left, right, or forward.

This virtual teacher and classroom paradigm yields quantitative measures of: (1) Attention to Task: number of targets correctly noted and average reaction time for correct targets; (2) Teacher-Directed Attention to Task: based on virtual teacher's visual regard, assessment of number correct and average reaction times relative to virtual teacher orientation (e.g., teacher looking forward, teacher looking left, and teacher looking right) conditions; and (3) Attention to Tasks during Social and Non-Social Distracter: the number of targets correctly noted in Social, Non-Social and No Distracter conditions and related average reaction times. It is expected that this research paradigm will provide information related to performance with and without social cuing from the teacher. Research with a previous version of the Virtual Classroom indicates performance measures on this task revealed test–retest and construct validity relative to performance on the Conners CPT II task, rs = 0.51–0.79, ps < 0.025 [10]. However, the VR classroom measures were more sensitive to differences in attention among children with ADHD or typical development, ds range from 1.59–1.96, than the CPT attention measures [10, 95].

7.7 Conclusions

Differential diagnosis and treatment of neurodevelopmental disorders that impact the brain's frontostriatal system require assessments that can differentiate the overlapping symptoms. This chapter reviewed the ways in which previous research has most often relied on paper-and-pencil and computerized psychometric tests of executive functions. Again, although these approaches provide highly systematic control and delivery of performance challenges, they have also been criticized as limited in the area of ecological validity. A possible answer to the problems of ecological validity in assessment of executive functioning in HFA children is to immerse the child in a virtual classroom environment where s/he interacts with a virtual human teacher. Recent work by Parsons at the University of North Texas has combined the attentional assessment found in a virtual classroom environment with virtual human technology. The idea is to place a virtual human teacher with verbal and nonverbal receptive and expressive language abilities into the virtual environment to aid in assessment of joint attention. The virtual human teacher acts as a social orienting system that comports well with the social orienting hypothesis of autism. As a result, researchers may differentiate attention deficits that exist regardless of social facilitation from those executive functions that may be alleviated by a virtual teacher.

It is important to note that not all children respond to any given treatment in the same way. Therefore, in beginning a program of research on VR applications to intervention with HFA children it is judicious to anticipate that individual differences in treatment responsiveness will be observed and need to understood. Specific to VR applications it is not yet clear whether HFA all children respond equally to moderately or maximally realistic VR social environments, or VR environments with greater or lesser stimulus complexity. However, research does indicate that, although HFA children self-report a typical level of presence in VR environments, they also report significant differences in sense of presence ranging from mild to strong [87]. "Presence" refers to a sense of "being there" inside a virtual environment and this may moderate the learning effectiveness of VR experiences across individuals [61]. Differences in presence may be related to the type so previously noted stimulus presentation parameters. However, differences in presence have also been related to differences in aspects of cognitive style such visual field independence [96], which is a strength for many but not all HFA children.

It is important to recognize, though, that VR interventions may be best used in conjunction with other in vivo social intervention methods to enhance the probability of improved treatment with pervasive developmental disorders. Used in isolation some children may simply learn how to use or respond to the VR "program" rather than see its relations to the real world. Parsons et al. [18] recommends that VR interactions be practiced in conjunction with intervention provided by a therapist-mentor, rather than in isolated context that entirely replaces real world interactions and therapy. Phenomenological reports suggest this "VR/mentor method" serves to help HFA children maintain the connection between the VR practice and real life scenarios.

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