2022

ASD Social Skills Development Using Immersive Virtual Environment Head-Mounted Display Interventions: A Review of Feasibility and Effectiveness

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ASD SOCIAL SKILLS DEVELOPMENT USING IMMERSIVE VIRTUAL ENVIRONMENT HEAD-MOUNTED DISPLAY INTERVENTIONS: A REVIEW OF FEASIBILITY AND EFFECTIVENESS

A MASTER'S THESIS

SUBMITTED TO THE FACULTY

OF BETHEL UNIVERSITY

BY

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IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE DEGREE OF

MASTER OF ARTS

MAY 2022

BETHEL UNIVERSITY

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May 2022

APPROVED

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Abstract

This literature review determined the feasibility and effectiveness of Immersive Virtual Environment (IVE) virtual reality head-mounted display (HMD) interventions to develop social skills for children with ASD. Data summarized 11 research studies conducted within the past five years utilizing HMD interventions. The research examined several HMD technology options across various settings such as school, home and community. Analysis of the data found that HMD interventions demonstrated promise in terms of feasibility developing social skills for children with ASD. The review noted limitations of the reviewed studies as well as suggested a need for further research in this emerging field of ASD virtual reality interventions.

Table of Contents

CHAPTER I: INTRODUCTION

Autism spectrum disorder (ASD) refers to a spectrum of atypical pervasive neurodevelopmental conditions characterized by perpetual deficits in social communication, interactions, language, and competencies. This condition is associated with high morbidity, with deficits impacting daily life. Challenges include interpreting social interactions, maintaining eye contact and attention cues (Amaral, 2018). The communication deficits are demonstrated alongside restricted and repetitive patterns of behavior, interests, and activities (American Psychiatric Association, 2013). Impairments in expressive language, extensive difficulties with social interaction, and repetitive behaviors create many challenges for children with ASD (Kjellmer et al., 2012). The prevalence of ASD has increased dramatically over the past decade (Baio, 2014), with the total number varying across the world. An estimated 3.5 million people were diagnosed in the United States alone (Sahin, 2018), with 1 in 54 children diagnosed with ASD (CDC, 2020). Some survey results even indicate that up to 1 in 40 children in the United States carry an ASD diagnosis (Ravindran, 2019).

Levels of general functioning are heterogeneous amongst individuals with ASD (Dechsling, 2021), with social challenges often not being the only challenges faced by the children. They also often demonstrate symptoms such as irritability, inattention, impulsivity, and hyperactivity (Vahabzadeh, 2018) which can be attributed to attention-deficit/hyperactivity disorder (ADHD) (Columbi, 2017). Lack of expressive language ability, alongside subtle difficulties in social interactions and restricted and repetitive behavior patterns, create many obstacles for children with ASD when it comes to adherence to routines in their daily life (Horwitz et al., 2020). Unfortunately, symptoms of ASD are commonly a burden for both the individuals with ASD and their family caregivers (Vahabzadeh, 2018). Children with ASD have challenges understanding the subtle nuances of commonplace interactions (Beach, 2016). Navigating through childhood and adulthood can be challenging for all individuals regardless of brain development, though is often even more challenging for individuals with ASD due to the communication deficits (Beach, 2016). The increased prevalence of ASD is partially due to increased awareness among professionals and parents, as well as improvements in diagnostic procedures, and early detection (Blumberg, 2013).

Difficulties with ASD translate to the educational environment as well. It is commonly reported that individuals with ASD demonstrate significantly more school refusal behaviors than their neurotypical peers (Munkhaugen et al., 2017). Children with ASD also have trouble making sense of the often unpredictable school social environment and social stimuli (Lüddeckens, 2020). Compared with typically developing peers, children with ASD reportedly have lower quality and less reciprocal relationships, with a lower acceptance by their classmates (Chamberlain et al., 2007). Worse, many children with ASD are the victims of bullying during the school years (Skafe et al., 2019).

The previously mentioned impairments defining the disorder make social skill development an imperative goal in educational interventions for children with ASD (Dechsling, 2021). Furthermore, children with this neurodevelopmental condition need effective interventions to improve not only the core symptoms of ASD but also the comorbid presentations tied to the disorder (Berenguer, 2020). Research continues to show an important need for practical and focused support targeting core symptoms (Ravindran, 2018).

As research grows in the area of neurodevelopmental disorders, researchers have adapted to leverage new technologies that support children toward developing social interaction abilities (Beach, 2016). The use of ever changing and innovative technology solutions is hardly new, technology solutions have shown a significant uptick during the past 20 years (Grynszpan, 2014). New digital tools have shown promise for effective assessment and monitoring of a child's cognitive processes and behavior compared to traditionally used tools and assessments (Vahabzadeh, 2018). Undoubtedly, innovative assistive technology tools indicate a strong usefulness toward helping to address the demands of the ASD community (Sahin, 2018) while importantly, these tools demonstrate effective intervention in addressing the needs of people with ASD (Vahabzadeh, 2018). Technology interventions have been indicated and researched as early as the 1970s for ASD populations (Ravindran, 2018). Now more than ever, effective technology interventions are available to support children with ASD, especially in the area of joint attention and social communication (Bakeman & Adamson, 1984). Individuals with ASD present severe challenges with joint attention and social communication (Dawson et al., 2004). The encouraging results of technology use within the ASD population have generated widespread enthusiasm for more innovation. Modern technology solutions, such as the use of immersive virtual environments (IVEs), seem progressive regarding social skills instruction and present a cost effective way to meet the social, emotional, and educational needs of children with ASD (Dechsling, 2021). Immersive virtual environment interventions not only apply to ASD, they are being studied for a variety of conditions, including post-traumatic stress disorder (PTSD), social skill challenges, anxiety conditions, and phobias (Beach, 2016). Interventions in this area continue to branch out in new ways, incorporating hand-held technology tools for assistive technology. The presenting benefit is portability and a capability that has never been seen before (McNaughton, 2013).

IVE technology solutions show encouraging promise for use in children with ASD (Beach, 2016). IVEs recreate physical environments by formulating experiences that draw attention to the senses via sight, hearing, touch or smell (Beach, 2016). The virtual environments provide appealing tasks and activities that cannot always be offered in real-world contexts, while simulating real-world or creating fictional settings (Ravindran, 2018). IVE technology provides a full experience for the user, allowing the child to not only interact with and respond to the virtual environment, but for the virtual environment to respond to the child and the child's actions (Beach, 2016).

Artificial reality (AR) and virtual reality (VR) are the two main types of IVEs (Quintero, 2019). AR is a recent technology that lays out simulated auditory and visual information adapted to the real-world environment. This is often prepared and presented through handheld technology such as a tablet or smartphone, though can also include AR-glasses (Dechsling, 2021). AR expands the reality of images, combining both real and virtual elements to create an interactive virtual environment. AR use can overlap the real, physical world (Craig, 2013). Similarly to AR, VR technology simulates real world scenarios in artificial environments by using stimuli with realistic senses that surround and engage the participant (Dechsling, 2021). VR ultimately enables virtual interactions through engaging experiences (Berenguer, 2020). Interestingly, AR is often not as artificial as VR, focusing mainly on allowing the user to interact in a physical world. This means AR is more versatile and simpler than VR because of the use of a range of devices, such as a smartphone or table, which encourages interaction in the real, physical world. (Berenguer, 2020). Due to VR being more artificial, a specialized headset is often required for the use (Quintero, 2019).

There have been promising outcomes from previous research on IVEs, to include VR and AR, that expand to a wide range of individual needs (Ravindran, 2018). AR has emerged as an effective tool in the medical field, such as in medical diagnosis, mental health treatment, promoting well being (Lim, 2019). Over the last decade, there has been a significant increase in the number of publications focused on computer-based VR/AR studies and interventions involving individuals with ASD (Dechsling et al., 2020), as well as AR intervention that continue to be studied to address the needs caused by many neurodevelopmental disorders (Berenguer, 2020). VR is even being used in neuro-rehabilitation with promising results (Salisbury et al., 2016).

Studies involving IVEs have mainly focused on social and emotional skill development, with reported benefits exhibited after skill building developed within the virtual interventions (Dechsling, 2021). Studies continue to demonstrate that IVE interventions improve socioemotional skills, such as attention and daily functioning in ASD (Vahabzadeh, 2018). Looking within the educational setting, AR has been studied as a tool to improve the educational outcomes of children with disabilities including children with ASD (Vahabzadeh, 2018).

IVE interventions encourage individuals to manipulate and adapt to a virtual and realistic world. This presents major advantages over more traditional interventions for individuals with ASD (El-Seoud, 2019). The applications presented in the virtual environment allow for children with ASD to participate in multimodal interactions that encourage growth and learning (Quintero, 2019). IVE interventions can be presented with various tools such as Cave Automatic Virtual Environment (CAVE), hand-held devices, desktop computers, and head-mounted displays (HMDs) The elements presented in IVEs are relevant and meet the needs of individuals with ASD because they allow the individual to modify the virtual environment that supports generalization (Stickland, 1997).

One facet of IVEs are head-mounted displays (HMDs). HMDs are goggles that present users with a total virtual environment that encompasses full visual involvement with the virtual world (Dechsling, 2021). The HMD experience exhibits a three-dimensional display providing a realistic and natural viewing picture (Beach, 2016). The visual displays embedded in the HMDs can even be enhanced with additional IVE tools such as gloves and body sensors, providing the user with haptic feedback (Beach, 2016). When comparing HMDs to handheld devices incorporating AR technologies, it is important to note that handheld devices require the user's hands to hold the device, while simultaneously encouraging the user to keep a head-down posture toward the physical world (Sahin, 2018). Because HMDs are head-worn, they pose an advantage toward allowing the user to remain heads up and hands free when using them. This allows for better engagement with the social world (Sahin, 2018). There are many types of HMDs, though recent advances in technology have introduced smart glasses as a new and lightweight form. These face-worn smart glasses have built-in sensors and a visual display for assistive apps (Sahin, 2018). The increased functionality of the smart glasses provide for a wide range of experiences in the IVE (Barfield, 2015).

The emergence of the new smart glasses technology resulted in encouraging research data (Sahin, 2018). One type of encouraging technology is called Superpower Glass (SG), a wearable technology tool designed using Google Glass artificial intelligence glasses and a smartphone app to improve social skills for children with ASD (Voss et al., 2019). This smart glasses tool helps the user identify stimuli in their physical world (Kothari, 2017) by identifying facial expressions and proving social cues (Voss et al., 2019). SG is creatively designed to help individuals with ASD develop social and cognitive skills (Sahin, 2018). Empowered Brain System (EBS) is another type of smart glasses technology showing encouraging results for children with ASD. EBS is a wearable tool designed to improve social communication skills for individuals with ASD by helping the user recognize and decode human faces and facial expressions. EBS provides users with visual and auditory cues and guidance (Vahabzadeh et al., 2018), while running off apps that run on smartphones such as Google Glass (Keshav et al., 2018). The Oculus Rift and Google Cardboard are other wearable immersive reality technology. The Oculus Rift provides the user with a 360-degree fully immersive experience (Amaral et al., 2018), while Google Cardboard is a low-cost HMD that has similar features to the Oculus Rift (Ravindran et al., 2019).

HMDs are being developed and studied as an effective behavioral and social communication tool to assist individuals with ASD (Sahin, 2018). Immersive virtual environments offer bold new strategies, create opportunities to target the needs of individuals with ASD, and promote sustained progress toward optimal functional outcomes (Ravindran, 2018). The following literature review examines the feasibility and effectiveness of immersive virtual environment head-mounted display interventions developing social skills for children with ASD.

CHAPTER II: LITERATURE REVIEW

Factors Contributing to IVE Research

In searching for relevant studies, studies from 2016-2021 were prioritized and several databases were used to locate psychological literature. These databases included the Bethel University Library, JSTOR Arts & Sciences, EBSCO MegaFILE, and Education Journals. For the purpose of online search, search phrases were created by combining the terms "virtual reality," "head-mounted displays," "immersive virtual environment," and "artificial reality," with each of the following terms: "autism," "autism spectrum disorder," "social skills," and "social development" (e.g., virtual reality and autism"). Because these topics are a modern emergence in the area of autism, only studies published within the last five years were considered. The structure of this chapter is to review the literacy on immersive virtual environment interventions in this order: Feasibility of Immersive Virtual Environment Interventions; Feasibility of Interventions for Joint-Attention; Feasibility of Interventions for Social-Emotional and Behavioral Functioning Skills.

Feasibility of Immersive Virtual Environment Interventions

Sahin et al. (2018) investigated the usability and acceptability of using virtual reality computerized glasses with children with ASD and their caregivers. The researchers used a new smart glasses technology called Superpower Glass (SG), a wearable technology tool designed using Google Glass artificial intelligence glasses and a smartphone app to improve social skills for children with ASD (Voss et al., 2019). SG promotes emotion recognition and facial engagement by identifying facial expressions and proving social cues (Voss et al., 2019). The researchers were acutely interested in the feasibility of using SG with the children despite the potential stigma of use, and whether the children's caregivers would find the glasses to be a positive experience. The results of the study showed that all participants found the glasses stress-free during use, with no perceived sensory or emotional challenges associated. Importantly, all participants reported they would be willing to wear the glasses in both home and school environments. Lastly, the majority of caregivers felt the experience was positive and that the glasses were fun for the children (Sahin et al., 2018).

The study recruited eight students with ASD as participants, with the intent to experiment with the smart glasses in a controlled environment. The children ranged in age from six to 17 years, with an average age of 11, and included seven males and one female. Caregivers were provided a seven-point scale to rate their child on overall ASD functioning. A rating of one was considered the lowest functioning, and a rating of seven was considered the highest functioning. The caregiver scores for the eight study participants averaged to 5.6 (Sahin et al., 2018).

The caregivers and participants were oriented to a testing room, where the participants were given smartglasses to properly place on their face, aligned with their eyes. After testing was conducted, participants and their caregivers were questioned about their experience using the glasses. Participants were asked if they would use the glasses at home and at school, while caregivers were questioned about whether they thought the experience was fun, and if the experience had gone well (Sahin et al., 2018).

The results of the study were extremely encouraging. All participants successfully wore and interacted with the smart glasses. No negative effects were recorded. All participants reported they weren't stressed with the experience, and that they were not overwhelmed by sensory items. Encouragingly, the participants all reported that they would be willing to use the smart glasses at home and school settings for one hour each day (Sahin et al., 2018).

The caregiver reports were similarly encouraging. All caregivers reported that they felt agreeable to their children using the smart glasses at home and at school, and that they had no concerns with their child using the smart glasses. The majority of caregivers also reported that the overall study experience was more positive than they expected (Sahin et al., 2018).

Overall, this study suggested that virtual reality smartglasses are an accessible tool that promote self-sufficiency for children with ASD. The results of this study demonstrated the importance for continued research in the use of virtual reality glasses (Sahin et al., 2018).

Daniels et al (2018) conducted examining the feasibility and effectiveness of using the Superpower Glass (SG) software to support the social learning and acuity of children with ASD. Superpower Glass (SG) is a new, wearable technology tool designed using Google Glass artificial intelligence glasses and a smartphone app to improve social skills for children with ASD (Voss et al., 2019). SG promotes emotion recognition and facial engagement by identifying facial expressions and proving social cues (Voss et al., 2019). The researchers hypothesized that using the SG system would increase social skills, facial recognition and eye contact in children with ASD and would be an effective and practical wearable therapy intervention for home use. The study showed promising results, indicating not only the feasibility of using mobile technologies as therapeutic tools for children with ASD, but also the effectiveness of using mobile technologies to build social skills, with caregivers reporting greater social acuity and increased eye contact for their children.

The participants in this study were selected by referrals from the ASD and Developmental Disabilities Clinic at Stanford University and the Developmental Behavioral Unit of Lucile Packard Children's Hospital, as well as advertisements announced at various academic conferences and social media sites. Families were included if their child had a verified medical diagnosis of ASD and was between the ages of three and seventeen. The study was conducted using the SG connected to an app on an android smartphone. The app was designed to teach children with ASD the eight universal emotions and improve social awareness and eye contact. While wearing the Google Glass hardware, the child was assisted by the software, helping them identify emotions shown by a communication partner in their natural environment. The app offered two game-modes and a free-play mode, providing the child feedback via audio or audio and visual emoticon. Each family completed an in-person orientation at Stanford University and at least three 20-minute sessions per week. Over the course of the study, families had the device on average for 72 days or 10.29 weeks, with the mean minutes of total app usage being 409 minutes (Daniels et al., 2018).

The results of this study were encouraging in all three facets of collected data. First, the Social Responsiveness Scale (SRS-II) data collected showed that on average, scores decreased 7.38 points from 80.07 at the intake to 72.93 at the conclusion appointments. A higher SRS-II score indicates a higher severity of ASD, and the study had six participates move from one ASD severity class to a lower ASD severity class (four from “severe” to “moderate,” one from “moderate” to “mild,” and one from “mild” to “normal”). Eleven families had Emotion Guessing Game (EGG) facial recognition task scores from the intake and conclusion meetings which exhibited significant increases in emotion labeling accuracy from 28.45 at intake to 38.00 at conclusion. There was no correlation regarding the amount of time each student was exposed to the SG intervention, which ranged from four to nineteen weeks. The results from the semi-structured qualitative interviews completed at the conclusion of the study similarly reported positive results. Twelve of fourteen families reported that their child’s eye contact skills increased from the beginning to the end of the intervention period. It is important to note that this study did not use a control group, and so reported changes cannot be compared to a group who did not receive the SG intervention (Daniels et al., 2018).

This study showed encouraging data in terms of the feasibility of the use of the SG system by families of students with ASD at home. The results of the study showed significant decreases in SRS-II scores, which signified a decrease in ASD symptom severity. While the study originally included 24 families, five chose to not continue with the study prior to the intervention period and five were not included in the data due to lack of completing the intervention instructions. The remaining 14 families had positive feedback about the Superpower Glass (SG) system in the post-intervention qualitative interview. One limitation of the study was that three families were not given the EGG intake evaluation, therefore, post-data could not be properly compared. Another limitation was that this study required families to come for three in-person sessions at Stanford University in California, which may have limited the ability for families without transportation to participate. Additionally, due to the nature of the study, families who were less comfortable with technology may not have chosen to participate so the results may reflect attempts by families who already supported technology interventions. The study relied on SRS-II reports by family members. Family reports have not accounted for placebo effects reflected in the results. Finally, the study did not include a control group, so comparisons were not made between the intervention group and a control group (Daniels et al., 2018).

Despite the limitations, the study showed encouraging changes in SRS-II feedback, EGG intervention feedback, and qualitative interview reports from the families. The results of the study supported the feasibility of using headset-based technology interventions to positively affect the social skills abilities of students with ASD. Future research should continue to explore these options both in school and home settings using larger groups of participants reflecting more diverse members of the ASD community (Daniels et al., 2018).

Liu et al. (2017) conducted a study on the feasibility of virtual reality smart glasses for young boys with autism spectrum disorder (ASD) to improve social communication and behavior regulation skills. The researchers used the Brain Power System (BPS), a behavior aid focused on helping children with ASD understand emotions, improve eye contact, develop better self-control, and improve face directed-gaze. The intention of the BPS was to enhance cognitive and social skill development for individuals with ASD. The study was designed to support two boys via coaching sessions with the smart glasses to improve social skills. Encouragingly, improvements in social skills were reported after just one coaching session with the smart glasses (Liu et al., 2017).

In the study, researchers trialed the BPS system with two males, ages eight and nine, who had a medical diagnosis of autism spectrum disorder. The study also included their caregivers for data collection purposes. Each child participated in a single behavioral coaching session. Data was collected through the Aberrant Behavior Checklist (ABC), a scale that measured behavior symptoms for individuals with developmental disorders. The scale includes five domains: lethargy/social withdrawal, hyperactivity/non-compliance, inappropriate speech, irritability/agitation, and stereotypic behavior. The ABC was completed by the caregivers during pre-intervention (coaching session) to collect baseline data, and post-intervention (24 hours after the coaching session). The caregivers also identified differences in their child's social communication and behavior before and after the intervention (coaching session) (Liu et al., 2017).

Following the pre-intervention ABCs, each boy was given one BPS coaching session using the *Face Game* and the *Emotion Game* BPS applications. The games are BPS-centric applications designed to help users with social skill development. The *Face Game* coached the user to visually attend to the face of another person to overcome challenges with gaze aversion and inattention. The *Emotion Game* coached users to recognize, identify, and assess distinctive facial emotions. The coaching intervention provided the children and their caregivers ample time to learn the BPS and accompanying applications. Caregivers provided the post-intervention ABC with documented behavioral information about their child 24 hours after the session (Liu et al., 2017).

The study findings not only demonstrated the feasibility of BPS, but its use also highlighted considerable behavioral improvements for both participants. No adverse effects were reported from the intervention for either participant or caregivers and the caregivers felt the BPS was highly tolerable, engaging, fun, and enjoyable for their child. They also reported high or very high ratings for ease of use (Liu et al., 2017).

Notably, both children demonstrated significant symptom reductions across all five ABC subscales between pre and post-intervention. The caregivers reported improvements in non-verbal communication, eye contact, and social engagement. Data analysis noted significant changes between pre and post-intervention. There was a significant reduction in hyperactivity/non compliance reported. The pre-intervention ABC reflected that 'User A' demonstrated a score of 18 out of a maximum 45 points on the subscale, irritability/agitation. The post-intervention ABC reflected that 'User A' demonstrated a score of 2. That demonstrated a drastic reduction in irritability and agitation symptoms. Similarly, pre-intervention data showed the following scores: 17 = lethargy/social withdrawal, 2 = stereotypic behavior, 19 =

hyperactivity/non-compliance, and 4 = inappropriate speech. Post-intervention data reflected a significant decline in all subscale scores, dropping to 0, 0, 4, and 0, respectively. ‘User B’ showed almost identical levels of improvement, from subscale scores of 14, 5, 3, 26, and 5 to 3, 0, 2, 8, 2, respectively (Liu et al., 2017).

The following study not only highlighted the overall feasibility and usability of using virtual reality smart glasses for individuals with ASD, but also demonstrated the promising potential smart glasses have in supporting social communication and behavior-regulation skills. One major limitation of this study was the limited sample size. Only two participants with ASD were included. Due to this, the findings could not be used to generalize with a broad ASD population, though the findings provided a solid footing for continuing research in this area. The researchers' noted that this study was the first study published that used augmented reality smart glasses as a behavioral aid with children. More research is needed using this tool specifically for children with ASD (Liu et al., 2017).

Feasibility of Interventions for Joint Attention

Ravindran et al. (2019) examined the feasibility of using a Google Cardboard virtual reality joint attention module intervention with school-aged children with ASD. Google Cardboard is a low-cost HMD with similar features to the Oculus Rift (Ravindran et al., 2019). The researchers primary objective was to investigate whether children tolerated and enjoyed using the virtual reality headsets. The secondary objective explored the effectiveness of the joint attention measure and its potential impact toward improving the joint attention skills in the children (Amaral et al., 2018). Intervention results indicated a high tolerance for the headsets and positive changes in joint attention skills for the participants, suggesting the module intervention was safe and tolerable for children with ASD (Ravindran et al., 2019).

The study included 12 children recruited from a private special education school ranging in age from nine to 16 with an average age of 13. Gender ratio included 10 male and two female participants. All children were medically diagnosed with ASD. Each caregiver rated their child's verbal skills. The results indicated a range of verbal abilities amongst the children, with three children rated as 'verbal', four children rated as 'minimally verbal', and five children rated as 'pre-or nonverbal' (Ravindran et al., 2019).

Google Cardboard, a virtual reality-based HMD, was used in the study in cohesion with a joint attention module software created by the researchers. This HMD provided participants an immersive three-dimensional display to explore the different scenarios presented in the intervention. The virtual environment presented in the study designed a safari-themed environment that included animals and a virtual avatar. Participants engaged in 14 HMD intervention sessions over five-weeks. While using the HMD, participants were asked to navigate a number of joint attention bids and respond to verbal prompts from the avatar. Participant engagement was tracked using the joint attention software (Ravindran et al., 2019).

Data collection relied on school staff reporting, and play-based behavioral assessments. Feasibility analysis results were promising. Over the five weeks of intervention, participants attended over 80% of the sessions. Participants demonstrated tolerating the HMD based on their enjoyment over 95% of the time. Joint attention data results showed that 10 of the 12 participants improved in at least one key area, and nine out of 12 participants demonstrated an improvement in total interactions from pretest to posttest. When assessing from eye gaze, seven out of 12 participants showed improvements, while four participants demonstrated a pronounced improvement from pretest to posttest. The study results demonstrated both the feasibility and effectiveness of using a Google Cardboard HMD intervention to develop joint attention skills in children with ASD. The researchers indicated that HMDs, especially low-cost HMDs such as Google Cardboard, presented an innovative new trend for teaching children with ASD that should continue to be researched (Ravindran et al., 2019).

Amaral et al. (2018) conducted a study in Portugal on the feasibility of using Oculus Rift virtual reality glasses with young adults with autism spectrum disorder (ASD) to improve social attention. The Oculus Rift is a wearable HMD that provides the user with a 360-degree fully immersive experience. The study examined whether an EEG brain computer interface (BCI), coupled with the Oculus Rift, could be used to teach social cognition skills. Multiple sessions were conducted over 17 weeks, with eye-tracking technology used within the glasses to monitor the participants eye movements within the virtual environment. The identification of social attention items was a point of emphasis. Overall the study supported the feasibility of using a virtual reality intervention to teach joint attention skills to individuals with ASD (Amaral et al., 2018).

Fifteen adolescents and adults with an average age of 22 years and 2 months, participated in the study. Each had a medical diagnosis of ASD. None of the participants had an intellectual disability. Participants attended study sessions over multiple months. Outcome assessments were performed at three intervals: baseline, post-training, and follow-up. Baseline assessments were conducted at session zero, post-training assessments were conducted at session seven, and follow-up assessments were conducted at six months post-training (Amaral et al., 2018).

During sessions, participants were asked to wear an Oculus Rift DK 2 headset while sitting in an office chair in a quiet and spacious room. Multiple 360 degree animated images and scenarios were presented to the participants while their eye movements were recorded with an eye-tracking software. The presentation of virtual reality created a fully immersive environment for the participants (Amaral et al., 2018).

Animations within the scenarios presented joint attention cues for which the participants' eyes were tracked for eye fixations. EEG data was obtained from electrodes placed on multiple locations on the participants head through an EEG cap. Since this was a feasibility study to assess the effects of using this specific virtual reality headset technology for individuals with ASD, no hypothesis for data was presented by the researchers (Amaral et al., 2018).

The study results showed that the eye-tracking assessment did not result in a significant change in the total number of social attention items identified. However, while the study showed inconclusive results for joint attention training, the results met the intended purpose that demonstrated the feasibility of using virtual reality glasses with individuals with ASD. More studies are needed in the area of virtual reality glasses and ASD (Amaral et al., 2018).

Feasibility of Interventions for Social-Emotional and Behavioral Functioning Skills

Voss et al. (2019) conducted a study in California on the efficacy of using a wearable head-mounted virtual reality behavioral intervention for enhancing social skills for children with ASD. The researchers used a new smart glasses technology called Superpower Glass (SG), a wearable technology tool designed using Google Glass artificial intelligence glasses and a smartphone app to improve social skills for children with ASD. SG promoted emotion recognition and facial engagement by identifying facial expressions and proving social cues. The participants were split into two groups, an intervention and a control group, with the intervention group using the SG four times per week for 20 minutes over six weeks. Socialization measures were used throughout the study to assess progress. The results of the study were promising, with the intervention group showing improvements in one of the main adaptive behavior measures.

The researchers stated that to their knowledge that this was the first randomized clinical trial that demonstrated efficacy of a wearable behavioral intervention for children with ASD (Voss et al., 2019).

Researchers recruited children between the ages of six and 12 years, who were medically diagnosed with ASD, and who currently received applied behavior analysis (ABA) therapy a minimum of twice per week. After screening for eligibility, 71 participants were enrolled, with 40 selected for the intervention group and 31 selected for the control group. The study was split between an intake phase and posttest phase (six weeks after initial intake). Data was collected for each group that included Social Responsiveness Scale (SRS-II), the Vineland Adaptive Behavioral Scales II (VABS-II), the Developmental Neuropsychological Assessment, Second edition (NEPSY-II), and the Emotion Guessing Game (EGG). For both groups, the SRS-II and VABS were administered during the intake phase, and the SRS-II, VABS, NEPSY-II, and EGG were administered at the posttest phase. The researchers provided a SG to the invention group, requesting that it be used three times per week for 20 minutes, and one time per week when working with the ABA behavior interventionist, for a total of four occurrences per week. The control group was not provided a SG, though continued with the current ABA therapy a minimum of twice per week (Voss et al., 2019).

The SG system provided to the intervention group demonstrated two forms of visual cues to help users recognize and classify eight different emotions. Visual feedback was the primary form of assistance, though audio feedback was available if the user or their caregiver enabled it on the SG. When the user looked at the face of a family member or friend, the SG indicator illuminated and detected the face and then revealed an emotion icon that identified the emotion to the user. The SG's data was saved in the mobile app, which was the management center for the user's SG. In this study, the children's caregivers operated and monitored the mobile app. Three engagement activities were available to the children and caregivers, providing choices in how they wanted to use the SG. The caregivers were key to providing valuable data during the intake phase by completing the SRS-II and VABS. They also completed the same assessments at the posttest phase, six weeks later (Voss et al., 2019).

The results of the study showed positive findings related to the effectiveness of using the SG to teach children with ASD. There were significant improvements in VABS scores between the intake phase and posttest phase for children in the intervention group. Differences amongst groups were not observed for other measures. Since the VABS was an assessment tool that measured communication and socialization in daily living and adaptive behavior, it was encouraging to see significant improvements for the intervention group compared to the control's group. One limitation noted was that researchers only focused on children who currently received weekly ABA therapy. Broadening research to include children not receiving ABA therapy would indicate whether similar results could be obtained for the broad ASD population. Overall, the findings indicated that the SG intervention could effectively improve social skills for children with ASD who received ABA therapy (Voss et al., 2019).

Vahabzadeh et al. (2018) investigated the efficacy of using a virtual reality tool designed to support the social communication and hyperactivity needs of students with autism spectrum disorder (ASD). The study looked closely at changes in social communication, irritability and ADHD symptoms such as hyperactivity, inattention, and impulsivity after subjects with autism were introduced to a smarglasses program called Empowered Brain System (EBS). EBS consisted of a wearable smart glasses technology tool designed to improve social communication skills for individuals with ASD by helping users recognize and decode human faces and facial expressions. EBS provided users with visual and auditory cues and guidance while utilizing apps that run on smartphones such as Google Glass (Keshav et al., 2018) (Vahabzadeh et al., 2018).

In this study, researchers introduced the EBS to students in two stages: the feasibility stage, which was the initial three weeks of the study, and the efficacy stage, the final three weeks of this two-part, six week study. A single-subject design examined the effects of the smart glasses intervention for four students in a public school setting in Massachusetts. This was a convenience sample of four students who had a formal ASD diagnosis and a school IEP. All four students were male with ages that ranged from 6.7 to 8.8 years. The Empowered Brain program was designed to be administered by a facilitator in 10-minute sessions. The researchers in this study followed a protocol using three educators in the school as facilitators. Stage one, the feasibility stage, included a baseline during the first week where students continued to follow in their normal school schedule. During the following two weeks, students received two 10-minute sessions of EBS facilitated by their teacher. This stage was designed to assess the feasibility of using the EBS in the school setting. The educators also completed an Aberrant Behavioral Checklist at the end of the baseline week and after the intervention period (Vahabzadeh et al., 2018).

At the conclusion of the feasibility stage, the researchers continued with the efficacy stage. This stage included a one-week control period, one week of the designed intervention and one intervention extension period which also lasted one week to better understand the long-term effects of the EBS intervention. At the conclusion of the study the educators completed a four-point Likert scale that rated how their experience using the EBS compared based on their use of other technology-based interventions they tried with students (Vahabzadeh et al., 2018).

The intervention design included the student wearing smartglasses while sitting across from their teacher. The glasses used the Face2Face module of the EBS which monitored the student's attention and offered auditory and visual feedback to the student, who gained points for attending to the conversation. Additionally, the feedback decreased as the student's attention improved but increased if the student became inattentive (Vahabzadeh et al., 2018).

The results of this study were encouraging. Though the sample size was small and this was not a blind study, the ABC ratings completed by the educators showed decreased irritability, hyperactivity and social withdrawal for all students. Compared to the baseline ABC rating, the students demonstrated an average 59.5% reduction in irritability, 37.6% reduction in hyperactivity, and a 80.1% reduction in social withdrawal. All ABC raters that completed the intervention with the student were educators, which included special education teachers and speech and language therapists (Vahabzadeh et al., 2018).

This study highlighted the positive results and realistic implementation of a smart glasses-based intervention in the school setting for students with autism. This technology-based intervention addressed three of the most defining characteristics of autism and was highly rated by educators as an effective easy-to-use intervention for the school-setting. One strength of this study was that it addressed the feasibility of using this intervention in the school-setting and confirmed that educators could properly implement the intervention into the daily academic routine. One weakness of the study was that it was the small sample size that included only four individuals with a single-case experimental design. Further research including a larger number of participants with various experimental methods is encouraged. Additionally, this technology-based intervention may have financial barriers for common use in schools (Vahabzadeh et al., 2018).

Overall, the study supported both the feasibility and efficacy of a technology-based, smartglasses-focused intervention for students with autism using the EBS. This study indicated that significant improvements in the areas of social withdrawal, hyperactivity, and irritability could be possible if this intervention was implemented in schools with special education programs (Vahabzadeh et al., 2018).

Beach and Wendt (2016) conducted a study in Tennessee to determine the effectiveness of using a researcher-designed virtual reality head-mounted display intervention to improve the social interaction skills in two male teenagers with autism spectrum disorder. The study was based on two research questions: Could students with autism spectrum disorder transfer and maintain skills learned in a virtual scenario and apply them to a real-life scenario? and, Could students with ASD alter their social interaction skills by with practice in a virtual immersive environment? The study emphasis was on the use of Immersive Virtual Environments technology (IVE). This new, promising technology replicated physical environments to immerse the user into a virtual environment that met the senses of sight, hearing, touch, and/or smell. The IVE accurately mimicked real-world environments and contributed significantly to the field of virtual reality technology research.

Two study participants were chosen in conjunction with a summer camp that lasted four weeks. The summer camp invited students who completed grades five through 12 to participate in activities tailored toward social skills development. The researchers felt the two participants chosen met proper criteria for the study due to their diagnosis of autism spectrum disorder, age, social ability level, self-awareness, and stage of life (Beach & Wendt, 2016).

One of the participants was 15 years old and challenged with fixating conversations around his favorite game, Minecraft. The other participant, aged 18 years, had difficulty maintaining eye contact and initiating typical conversations with others. Research-backed scripts were designed by the special education teachers at the camp to support and teach based on participant patterns of interaction weakness. The scripts provided critical information for researchers to create virtual events targeting specific weakness areas in the virtual reality environment (Beach & Wendt, 2016).

Each participant participated in virtual training conducted around three scenarios. Training for the 15-year old focused on bullying and adaptive conversation without fixation on Minecraft. Training for the 18-year-old targeted initiating conversations and maintaining eye contact. The teachers reenacted the virtual scenarios in real-life to assess the participant progress. As the study progressed, the scenarios were altered to help the participants develop flexibility and fade dependence on the scripts (Beach & Wendt, 2016).

The study findings showed staggering improvements for both participants. Both participants transferred skills learned in the virtual environment to the real-world environment. Both participants found the virtual environments to be life-like and engaging, while also reporting feeling less stress in the real-life scenario after training in the virtual environment scenario. When collecting data from both the virtual and real-life environments, researchers found that participants exhibited fewer nervous tendencies during the real-life scenarios. As the scenarios were altered, the teachers reported that they believed the participants were less rigid and more responsive. One teacher reported an improved use of eye contact for the 18-year-old (Beach & Wendt, 2016).

The researchers also demonstrated that participants also improved their social skills as a result of participating in the virtual environment. The 18-year-old participant improved the ability to engage in conversation. Data showed that he ‘Broke Eye Contact’ significantly less on week 4 of the study compared to week 1. The 15-year-old participant improved his ability to participate in conversations that made him feel uncomfortable, without initiating the topic of Minecraft. His results were similar to the other participant. Data illustrated that the topics of "Minecraft/Computers" decreased significantly from week one to week four (Beach & Wendt, 2016).

The study demonstrated significant implications for the use of the virtual reality head-mounted display for students with ASD. Since both the participants confirmed improvements in their own social interaction skills development area, the study encouraged more research with larger sample sizes conducted for the subject (Beach & Wendt, 2016).

Halabi et al. (2017) conducted a study in Qatar looking at the feasibility and effectiveness of using three interactive scenario-based virtual and augmented reality systems to improve communication skills for children with autism spectrum disorders. The study focused on virtual and augmented reality tools using different levels of immersion: Computer Augmented Virtual Environment (CAVE), Head Mount Display (HMD), and a standard desktop computer screen. Each tool was evaluated based on user satisfaction and the impact of immersive display. The researchers indicated that the following study on virtual reality systems was not intended as an intervention platform, but as a proof-of-concept application for children with ASD.

The researchers chose virtual-reality based systems that incorporated many interactive features to maximize immersion. The features included speech recognition through a wearable microphone, display and trackers (CAVE, HMD - Oculus Rift, and 20-inch LCD display desktop computer screen), gesture recognition to detect hand gestures, a realistic virtual environment with realistic avatars, and auto-navigation within the virtual environment. One scenario was created for use with all three systems. The scenario focused on greeting within the classroom setting, and integrated a familiar and realistic virtual classroom and avatar teacher (Halabi et al., 2017).

Once the user was immersed in each system, the scenario began by placing the user in the virtual world outside the virtual school. Within the scenario, the user auto-navigated into the school and into the virtual classroom. The user observed the virtual avatar teacher initiating a greeting verbally and gesturally by waving to virtual students within the class. After greeting all the virtual students, the avatar teacher greeted the user in the same way using a verbal and gestural greeting. It was expected that the user would respond to the avatar teacher. The response was recorded by the speech recognition microphone and gesture recognition device. The time was recorded, which indicated the time it took the user to respond to the avatar teacher. The scenario was then complete (Halabi et al., 2017).

The researchers intended to study children with high-functioning ASD aged 9-12, but were unable to study this population due to an unavailability of targeted participants. Because of this, researchers chose to study typically developing children of equivalent ages. They found that typically developing children, aged three to six, were closest in cognitive development to high-functioning children with ASD aged 9-12. To complete the study, participants were required to participate in two sessions (Sessions 1 and 2). The 20-minute sessions were held on separate days. The first session was used as a learnability session, where researchers guided and facilitated the use of different virtual reality tools with participants and their caregivers. Participants were introduced to and participated in the same scenario for each system one-by-one, beginning with the scenario on the desktop computer, then HMD - Oculus Rift, and last the CAVE with 3D glasses and trackers. Participants provided feedback about their experience following each session. During session two, the same procedures were conducted except that participants were provided with no guidance or facilitation from researchers. Participants were again asked to provide feedback about the experience after each session (Halabi et al., 2017).

The feedback provided was the basis for the data analysis. The results of the study indicated that all three augmented reality systems showed promise for user feasibility and satisfaction, with the CAVE environment being the most favorable amongst participants, followed by the HMD - Oculus Rift, and then the desktop computer. Minimal problems were faced using the systems. Participants reported that all three virtual environments were recognizable and easy to use with a minimal learning curve. System satisfaction was reported for Session One as follows: 88% (CAVE), 79% (HMD) 68% (Desktop). For Session Two, the satisfaction reported was: 91% (CAVE), 83% (HMD), 62% (Desktop). The level of immersion was rated using a 5-point scale, with a rating of five as the highest level of immersion and a rating of one as the lowest level of immersion. The immersion rated during Session one was: 4 (CAVE), 2 (HMD), 2 (Desktop). For Session Two, the immersion ratings were: 5 (CAVE), 4 (HMD), 3 (Desktop) (Halabi et al., 2017).

The findings from the study indicated that the virtual-reality based systems CAVE, HMDs, and Desktop Augmented Reality, could be feasible tools for developing communication skills for children with ASD. From the findings, the researchers felt that the CAVE provided the most immersive environment, thus would most likely have the greatest impact for children with ASD. The results indicated that the HMD - Oculus Rift had both a high satisfaction level and highly rated level of immersion, though lower than the CAVE. The Desktop model was noted to have significantly the lowest reported satisfaction and immersion levels. While conducting the study with typically developing children, the systems positively impacted almost all participants, indicating that similar results would likely be found for children with ASD. Further should be concluded using these systems with children with ASD (Halabi et al., 2017).

Keshav et al. (2018) conducted a study investigating the practicality of using a smart glasses-based technology socio-emotional learning intervention for children with ASD. The study was designed based on the use of Empowered Brain, a wearable smart glasses technology tool created to improve social communication skills for individuals with ASD by helping the user recognize and decode human faces and facial expressions. Empowered Brain provides users with visual and auditory cues and guidance (Vahabzadeh et al., 2018), while running off apps that run on smartphones such as Google Glass. The study sought to explore the relationship between internal (teacher's beliefs, confidence and perception) versus external barriers (availability of technology, training, and cost) barriers that may be associated with implementing smart glasses interventions for students with ASD in the school setting. The Empowered Brain provided auditory and visual guidance to students while they participated in an interaction with an educator and assisted them in understanding facial expressions and emotions (Keshav et al., 2018).

Keshav et al. (2018) used a single-subject analysis model to examine the attitudes and practicality options of teachers after a smart glasses socio-emotional intervention was implemented for 10 minutes twice a day for two weeks with a 13-year-old male middle school student with ASD. One general education and one special education teacher along with one paraprofessional participated in this model. Sixteen interventions were provided, eight for the general education teacher, seven from the special education teacher, and one from the paraprofessional. During the two-week intervention period, the school staff recorded their opinions about the practicality, the attitude toward the intervention, and how they viewed the impact of the intervention for the student via digital logs and in-person interviews with the researchers. Video interviews were recorded weekly and analyzed for common themes (Keshav et al., 2018).

Educator feedback was generally positive. The researchers first looked at the practicality of implementing this technology-based intervention. All three educators noted that the intervention was well-suited to implement in a classroom setting, and fun for the students. Additionally, they noted that the intervention was not time-consuming for either staff or students to learn. Regarding ease of use for the teachers and the students, the educators reported that the students found it easy to use and get used to, though the game function was slightly distracting for the students for the first few minutes. The student impact was also noted. The educators reported an improvement in student eye contact, verbal and non-verbal skills, participation, and conversational skills. However, the educator responses regarding student changes in attention were varied. Finally, the educators did not report any distractions or adverse effects for non-targeted students present in the classroom during the intervention (Keshav et al., 2018).

The strengths of this study included the in-depth interview and reporting process implemented to collect the qualitative opinions of the educators who used the intervention. The study found that educators reported high practicality and noted a generally favorable impact when using the Empowered Brain intervention. Several limitations should be noted however. This was a single-subject study; therefore it only investigated a small sample size. While the outcomes were generally positive, the same can not be assumed for implementing the intervention in a different school setting or with other students. Additionally, the study examined qualitative feedback regarding the implementation and did not note any quantitative results regarding the effectiveness of the intervention for student socio-emotional growth. Further qualitative research is needed to properly research the effectiveness and practicality of smartglasses-based socio-emotional interventions (Keshav et al., 2018).

Cheng et al. (2015) conducted a study in Taiwan to determine the effectiveness of a social skills intervention that used a head-mounted display (HMD), immersive virtual reality system for children with ASD. The 3D-SU system incorporated a virtual HMD (Model: I-Glasses PC 3D Pro), and a computer with an operating keyboard for items within the virtual environment. The intention of the 3D-SU system was to create a virtual environment that promoted social skill building in the targeted behavior areas of social cognition (SC), non-verbal communication (NC), and social initiations (SI). The following single-study, A-B-C (baseline-intervention-maintenance) design was facilitated with three children with ASD over six weeks. The findings were promising, demonstrating the effectiveness that using the 3D-SU system promoted social skill development in children with ASD (Cheng et al., 2015).

In the study, researchers identified a focus using an HMD-centric system to encourage individuals with ASD to develop social skills and social understanding. The 3D-SU was created using a 3D model software, and incorporated two virtual scenes for users: a classroom and a bus stop. Each environment incorporated social events and situations that required users to answer questions by making a choice using social problem-solving skills. When presented with a question, users made selections either verbally, or using remote control buttons. The system promoted social interaction, modeling, and awards of reinforcement. While in the virtual environment at one of the two virtual scenes, if a user answered a question appropriately, they were rewarded with a reward message and an animated applause sound. If the user responded incorrectly, a “Try Again!” message was displayed to invoke a corrective response from the user (Cheng et al., 2015).

Three boys with ASD, ages 10 to 13 years, participated in the study. They were recruited from their school settings. Each participant completed all three phases of the A-B-C design, and data was collected for all phases. Three sessions were completed for each phase (baseline, intervention, maintenance), over a total of six weeks. The researchers created two scales to measure the targeted behaviors. They called these scales the Social Events Card (SEC) and Social Behavior Scale (SBS), for which each assessed the targeted behaviors: SC, SI, NC (Cheng et al., 2015).

During the baseline phase, participants were assessed in the real-world, non-virtual reality environment. The time spent in the baseline phase differed per participant, though similarly, each participant was asked 12 questions randomly selected from the SBS, for which their responses were recorded. During the intervention phase, participants were individually led to a quiet room and were asked to participate in the 3D-SU system. They manipulated the virtual reality environment while wearing the HMD and utilized the computer keyboard, answering questions within one of the two 3D scenarios (bus stop or classroom) (Cheng et al., 2015). Three 30-40 minutes sessions were conducted while response data was collected. Last, during the maintenance phase, each participant was assessed in the real-world, non-virtual reality environment. During this phase, 20 days were spent to assess the lingering effects of the intervention for each child. Participants chose events from the SEC and were asked 12 questions from the SBS. Responses were recorded to determine whether the skills learned during the intervention lasted over a long duration of time (Cheng et al., 2015).

The results of the study were very promising. All three children showed improvements in targeted social skill behaviors from baseline to the intervention phase. Encouragingly, similar improvements were recorded during the maintenance phase. Not only was no decline in skill acquisition observed from intervention to the maintenance phase, all three children showed improvements in all three target behaviors during the same period (Cheng et al., 2015). While the 3D-SU system showed promise for the children, there were important limitations to this study. The researchers did not assess whether the results transferred in participants' real-life experiences. Researchers only assessed the skills within a controlled and consistent closed environment. The study also had a small sample size that made it difficult to know if the results would generalize to a broader population of children with ASD. Overall, the following study demonstrated promise that the 3D-SU system effectively taught social skills to children with ASD, though further research is needed on system implementation to assess a larger sample size (Cheng et al., 2015).

CHAPTER III: DISCUSSION AND CONCLUSION

Summary of Literature

With the prevalence of ASD increasing dramatically over the past decade (Baio, 2014) and with the ASD deficits impact on daily life (Amaral, 2018), new and innovative interventions are needed to address the ever changing needs of ASD children (Vahabzadeh, 2018). New innovative assistive technology tools continue to hit the market, providing alternative means for assessing and monitoring cognitive processes and behavior (Vahabzadeh, 2018). The tools strongly indicate usefulness toward addressing academic, social and communication demands for students with ASD (Sahin, 2018). One type of innovative technology tool is an Immersive Virtual Environment (IVE) which leverages virtual technology environments to provide children with ASD the opportunities to interact and complete tasks and activities in a simulated fictional world (Ravindran, 2018). The IVE immersive setting provides a full experience for the user, formulating situations that draw on user senses (Beach, 2016). Best yet, IVE seems progressively more promising for social skill development while presenting a seemingly cost effective way to meet the social, emotional, and educational needs of children with ASD (Dechsling, 2021). The previous literature review targeted the feasibility and effectiveness of using IVE technology tools, with an emphasis on new and modern HMD interventions.

Due to the fact that most research on HMD interventions is relatively recent, current research often focuses on the feasibility of using this form of technology with ASD populations (Amaral et al., 2018; Ravindran et al., 2019; Sahin et al., 2018; Liu et al., 2017; Vahabzadeh et al., 2018). Along with feasibility, researchers are targeting different areas of emphasis within HMD interventions. The three main areas of focus are application of virtually learned skills in the real world (Beach & Wendt, 2016; Daniels et al., 2018), improved social and behavioral skill functioning (Vahabzadeh et al., 2018; Halabi et al., 2017, Keshav et al., 2018, Cheng et al., 2015; Voss et al., 2019), and improved joint attention and/or eye gaze (Amaral et al., 2018; Ravindran et al., 2019).

As technology continues to advance, different forms of HMD technology tools become available for research (Sahin, 2018), with more and more functionality providing a wide range of experiences in the IVE (Barfield, 2015). Research interventions may focus on adapting popular VR HMDs such as the Oculus Rift or Google Cardboard (Amaral et al., 2018; Ravindran et al., 2019; Halabi et al., 2017), other research focuses on researcher-created HMD systems (Beach & Wendt, 2016; Cheng et al., 2015), while some focus on the highly encouraging Superpower Glass System (Sahin et al., 2018; Vahabzadeh et al., 2018; Liu et al., 2017; Keshav et al., 2018; Daniels et al., 2018; Voss et al., 2019).

Based on a research review of the feasibility for HMD interventions, the data is promising. All studies within the literature point toward high feasibility of use for the ASD population. Early studies on the feasibility of using a Google Cardboard for joint attention found that low-cost HMDs presented an innovative and promising solution for teaching children with ASD (Ravindran et al., 2019). Studies focused on the feasibility using the Oculus Rift and Google Glass Smart Glasses showed similar results (Amaral et al., 2018; Sahin et al., 2018; Liu et al., 2017; Daniels et al., 2018). The feasibility data is extremely promising because all studies reviewed in this literature review indicated a high HMD tolerability rating, with some as high as over 95% (Ravindran et al., 2019). Others reported that HMD-use was highly agreeable (Sahin et al., 2018). Importantly, reports concluded a high likelihood that students would wear HMDs in the school environment around their peers (Sahin et al., 2018).

Data for HMD interventions is also promising in the areas of application of learned skills in the real world, and social and emotional skill acquisition. The literature review points to improvements in social interaction skill development (Beach & Wendt, 2016) and decreases in ASD symptom severity that translate to home and school environments (Daniels et al., 2018). Significant improvements in social skill development were recorded which included, social withdrawal, hyperactivity and irritability (Vhabzadeh et al., 2018), positive impact to participant wellbeing (Halabi et al., 2017), increased student eye contact, improved verbal and non-verbal skills, participation, and conversational skills in the classroom environment (Keshav et al., 2018), improved social skills within targeted behaviors (Cheng et al., 2015), and significant improvements in behavioral assessment scores (Voss et al., 2019). Improvements in joint attention were inconclusive, with positive (Ravindran et al., 2019), and minimal improvements noted (Amarel et al., 2018).

Navigating life can be challenging for individuals with ASD due to their communication deficits (Beach, 2016). The deficits not only translate to the independent living and home environments, but also to educational environments (Munkhaugen et al., 2017). Impairments defining this disorder make social skill development an imperative target intervention goal for children with ASD (Dechsling, 2021). Overwhelmingly, research for IVE HMD interventions showed promising results in the areas of feasibility for children with ASD, along with social skill development that translateed to the real, physical world (Beach & Wendt, 2016; Daniels et al., 2018; Vahabzadeh et al., 2018; Halabi et al., 2017; Keshav et al., 2018; Cheng et al., 2015; Voss et al., 2019; Amaral et al., 2018; Ravindran et al., 2019). IVE HMD interventions also demonstrated practicality and feasibility resulting in improved social interaction skills (Keshav et al., 2018).

Limitations with Research

With IVE interventions being relatively new, the main limitations of HMD research can be reduced to the lack of high-quality studies facilitated thus far (Berenguer et al., 2020). Minimal research is available focused on digital intervention tools such as smart glasses, AR, and artificial intelligence (Vahabzadeh et al., 2018). More research is needed for commonly used assistive technology apps used with the ASD population (Vahabzadeh et al., 2018).

When looking at overall study practices, many studies identified that the virtual experience could be improved to better support participant outcomes (Amaral et al., 2018; Beach & Wendt, 2016). This included the lack of scenarios presented while using the HMD system, which provided less flexibility for developing participant skills (Beach & Wendt, 2016). A longer longitudinal study is also warranted to better understand participant outcomes (Keshav et al., 2018; Vahabzadeh et al., 2018; Liu et al., 2017. Application of interventions with same-aged peers is needed (Ravindran et al., 2019), and better coverage for those diagnosed with ASD (Nag et al., 2020; Halabi et al., 2017). Many studies also only used a single-case experimental design, even though an alternative theoretical approach would have further supported the validity of the study (Vahabzadeh et al., 2018).

Limitations in data collection practices were also noted. High-scoring opinion-based feedback assessments in an isolated research setting may not translate well to the complex, real world social environment of a school (Sahin et al., 2018). Also, the limited social skills of study participants may have impacted the accuracy of participant reporting. More reliable reporting procedures could be used in future research to ensure validity of the data (Ravindran et al., 2019). Additionally, data collection tools such as the eye-tracking tools may have distracted participants and impacted the accuracy of the data in measuring what was intended (Nag et al., 2020). Accuracy and reliability could have been improved by validating outcome measures to include quantitative measures as opposed to only qualitative measures (Keshav et al., 2018). The data collection methods used were often isolated to one specific test setting. The lack of data collection across multiple areas of the participant's life could have impacted the overall validity of the findings (Cheng et al., 2015). Improvements in data collection methods could provide researchers more concrete data to analyze and evaluate.

During many of the research studies, small sample sizes were used. This can be presented as a limitation, as small sample sizes translate to unreliable generalizability of results to the broader ASD population (Beach & Wendt, 2016; Vahabzadeh et al., 2018; Keshav et al., 2018; Cheng et al., 2015). The studies also presented limitations with the age of selected participants. This limitation interfered with generalizing the results to the broader ASD population (Nag et al., 2020; Dechsling et al., 2021). One large observed limitation was related to the participant gender ratios, as there were few female participants included in the studies (Nag et al., 2020; Liu et al., 2017). This limitation makes it difficult to understand whether the study findings could be genuinely reflected for the female ASD population. Additionally, there was limited variety in participant cognitive skills levels, with many studies only testing individuals with above-average IQs (Cheng et al., 2015; Nag et al., 2020). This limitation leaves much to be discovered around the impact of technology interventions for individuals with low to average cognitive ability.

Interventions tested in the research lasted only a short duration, with most only taking place for a number of days or weeks. A longer intervention duration could better reflect the general nature of behavioral interventions in ASD populations, as the goal of technology interventions was to be used over the long-term with students to see significant growth in social skill development and understanding (Vahabzadeh et al., 2018). Studies with long-term research could be beneficial to pursue to better understand the impact of technology-based HMD interventions in a school or home setting until graduation.

Implications for Future Research

There are many important areas to consider for future research. Areas such as participant samples, longitudinal research, technology tool diversification, and diverse environmental situations should be improved in future research. Future research should emphasize larger-scale participant sample sizes which would provide robust statistical interpretation and potentially more accurate generalizability with the broad ASD population (Vahabzadeh et al., 2018). This includes in-home research to better identify skill acquisition across multiple environments (Nag et al, 2020).

More research in the area of virtual environment interventions is needed for females and younger students with ASD (Liu et al, 2017; Nag et al., 2020; Dechsling et al., 2021). When looking at children with ASD, research is needed for a variety of age groups, specifically younger children (Dechsling et al., 2021). Future efforts should focus on recruiting gender and age-balanced sample sizes to identify potential gender differences that may influence outcomes (Dechsling et al., 2021).

To understand the use of technology-based interventions with the diverse ASD population, future research should provide interventions to a more diverse group with varied developmental profiles (Berenguer et al., 2020). More research is needed involving individuals with varying levels of disability, to include those with below average IQ (Cheng et al., 2015). Additionally, further research could include a greater number of teaching sessions (Liu et al., 2017). By including more teaching sessions, the research could more effectively predict the long-term success of similar interventions to implement in schools or in other learning settings.

Extended longitudinal research is needed to better understand the general decaying effects of technology interventions (Vahabzadeh et al., 2018; Keshav et al., 2018; Berenguer et al., 2020). The studies examined in this review were limited in duration and provided only a glimpse of the potential impact for people with ASD. Overall the interventions need to be longer to determine the long-term benefits or associated risks (Vahabzadeh et al., 2018).

Due to the development of technology tools available, future research should consider applying more tools to identify effectiveness across the broad ASD population (Berenguer et al., 2020). When considering the technology tools, research validation is also needed for commonly used assistive technology tools (Vahabzadeh et al., 2018). This includes applications used in HMDs (Ravindran et al., 2019), AR tools such as tablets and computers, eye tracking and joint attention tracking tools (Nag et al., 2020). Only a minority of studies about virtual environments apply to HMDs, so more research specifically in this area is needed due to the promising increase in usability (Dechsling et al., 2021).

Due to challenges in predicting peer social cues for children with ASD, more research is needed to determine how peers perceive HMD-use in school environments (Sahin et al., 2018). Future research should build on collaborative efforts between autism researchers, software and technology developers, educators working with children with ASD, and children with ASD within school, home, and community settings (Dechsling et al., 2021).

Conclusion

ASD is a disorder characterized by impairments in social communication, affecting not only the child with the condition, but their parents, siblings, peers, and teachers. The challenges presented by ASD often create barriers in relationships, independent living, and even general daily functioning. Sadly, children with ASD often show heightened anxiety around social interactions, and many experience bullying durig the school years. As advances in technology grow daily, new and innovative tools are readily available to help children with ASD who are impacted by social communication impairments. The results from this literature review provide hopeful new solutions for individuals with ASD and their families. Immersive virtual environment interventions have shown significant impact across multiple settings. This is very encouraging. As immersive virtual environments continue to become cost-effective and available, it's my hope that more research is conducted to include a broad range of individuals with ASD, and that state and federal systems will provide financial support to provide technology tools in home and school settings that better support children with ASD.

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