Improvement of ADHD-Related Symptoms in School Age Children and Young Adults with Autism via a Smartglasses-Based Socio-Emotional Coaching Aid

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Abstract

Introduction
People with autism spectrum disorder (ASD) commonly experience ADHD-related symptoms, including hyperactivity, inattention, and impulsivity. A third of people on the spectrum may be diagnosed with attention hyperactivity deficit disorder (ADHD). These dually diagnosed individuals often face barriers to ADHD treatment. Non-pharmacological technology-aided tools for hyperactivity and inattention in people with ASD are being developed, although research into their efficacy and safety remains limited. This preliminary report describes the changes to ADHD-related symptoms in children and adults with ASD after use of the Brain Power Autism System (BPAS), a behavioral and social communication aid for ASD based on augmented-reality smartglasses.

Methods
Eight children and adults with ASD (M:F ratio of 7:1, mean age 15 years, range 11.7-20.5 years) were recruited through a web-based research signup form. Four of these participants had a history of ADHD. The baseline score on the hyperactivity subscale of the Aberrant Behavioral Checklist (ABC-H), a measure of hyperactivity, inattention, and impulsivity, determined their classification into a high ADHD-related symptom group ($n = 4$, ABC-H ≥ 13) and a low ADHD-related symptom group ($n = 4$, ABC-H < 13). All participants attended a coaching session with BPAS, where they used smartglasses-based social communication and behavioral modules while interacting with their caregiver. Caregiver-reported ABC-H scores were then calculated at 24- and 48-hours post-session.

Results
All eight participants were able to complete the coaching session. ABC-H scores were lower post-intervention for most participants at 24 hours ($n = 6$, 75%), and for all participants at 48 hours ($n = 8$, 100%). At 24-hours post-session, average ABC-H scores decreased by 54.4% in high ADHD symptom group and by 20% in the low ADHD symptom group. At 48-hours post-session ABC-H scores compared to baseline decreased by 56.4% in the high ADHD symptom group and by 66.3% in the low ADHD symptom group.

Conclusion
Use of the BPAS, a smartglasses-based behavioral and social communication aid for school-aged children and young adults with ASD, was associated with reduced ADHD-related symptom burden. While there may be a placebo effect when using novel technology, this consideration should be tempered with knowledge that many people with ASD have been noted to react negatively to novel experiences and transitions. The observed effects are likely to be temporary, and further research is required to understand clinical importance of these observed changes. Future research on longer-term monitoring with a larger sample size is recommended.

Introduction

Autism Spectrum Disorder (ASD) is a lifelong developmental disorder characterized by challenges in social communication and the presence of repetitive behaviors and/or restricted interests. Many people with ASD experience symptoms of inattention and hyperactivity, and approximately one-third of people with ASD are diagnosable with attention deficit hyperactivity disorder (ADHD) (1, 2). Evidence from genetic, cognitive, and behavioral research suggests that when ADHD and ASD co-occur, they may be considered a separate overarching condition (3-5). The combination of ASD and ADHD in an individual has been linked to both greater cognitive impairment (6, 7), general psychopathology (8, 9), and significantly higher rates of some hyperactivity/impulsivity symptoms compared to individuals with ADHD alone (10).

While psychopharmacological medication is the leading treatment for ADHD, people with co-occurring ASD and ADHD have been found to be less likely to receive appropriate treatment for their ADHD (10), and appear to respond less favorably to treatment when compared to individuals with ADHD alone (11). Additional concerns about ADHD treatment, in particular stimulant medication, focus on their long-term effectiveness (12), side effects (13), and parental reservation about their use (14). Yet, evidence also shows that leaving individuals with untreated ADHD may lead to considerable negative social and behavioral sequelae, including greater risk of academic failure (15), alcohol and drug use (16), and contact with the criminal justice system.

There has been growing interest in the use of cognitive training in ADHD, a non-pharmacologic approach that may utilize neurofeedback and/or novel digital approaches. Recent studies have shown promise (17, 18) although historic interventions have raised questions regarding their effectiveness (19). There is also concern that technology may actually prove to be distracting, and reduce learners attentiveness to educational tasks (20-22).

Little research has described the impact of digital interventions on people with ASD who demonstrate ADHD symptoms (23). Augmented reality is a rapidly advancing technology that may help improve ADHD symptoms in people with ASD, and early reports suggest that it may be helpful in enhancing both selective and sustained attention in children with ASD (24). We have previously described the delivery of social communication coaching on augmented reality smartglasses via the Brain Power Autism System (BPAS) (25). Our report on two boys with ASD demonstrated short-term improvements in the hyperactivity subscale of the Aberrant Behavioral Checklist (ABC-H) (25), a validated instrument that assesses hyperactivity, impulsivity, attention, and non-compliance (26). The ABC-H has previously been used as a primary outcome measure in ADHD treatment studies in children with ASD (27, 28).

The Brain Power Autism System (BPAS)

The Brain Power Autism System (BPAS) is a combination of modern smartglasses and science-based modules (29, 30). Smartglasses are lightweight head-worn computers with a small clear display, and have the ability to provide guidance to users through both visual and audio cues (Figure 1). The BPAS has the ability to collect a considerable amount of user data through a complex in-built sensor array, including camera, microphone, touchpad, blink sensor, gyroscope, and accelerometer. The BPAS includes modules that utilize these sensors in order to deliver social communication and cognitive skills coaching. This digital approach may be particularly valuable to both people with ASD (31) and people with ADHD (32, 33).

Figure 1. Google Glass, prototypical head-worn smartglasses with in-built sensors, as well as a small screen and a bone conduction speaker to provide a private audio-visual experience. The BPAS integrates Google Glass with a range of assistive science-based modules.

For example, the BPAS incorporates the *Face2Face* app, software that helps guide users to pay attention to socially salient visual stimuli (human faces). The ability to pay attention to important social stimuli, and to direct gaze towards the most socially salient features of the face, have been identified as a key challenge in ASD (34). When the *Face2Face* app is running, the BPAS is able to identify the presence of human faces within its visual field, and through engaging visual cartoon-like images and guidance arrows, helps to direct the users towards the human faces. As the user proceeds to pay more visual attention towards the human face, they earn points and other in-game rewards. The points stop accumulating after a short period of time as a mechanism to avoid coaching users to stare. Using a similar technique, the BPAS can not only detect human faces, but when running *Emotion Charades*, can accurately detect human facial emotions. Users can then experience a game-like experience in which they identify the emotions of another person. The BPAS rewards correct answers with in-game rewards, or provide guidance when needed.

Additionally, the system incorporates mechanisms to alter the difficulty associated with using each gamified app. One method is to alter the attentional challenge by displaying virtual elements that will either help to enhance attention, or to act as distractors to the social stimuli that the user is tasked to interact with. These virtual elements are overlaid over the user's real-world view, and include dynamic real-time positional cues based on user movement and physiology, and reward-based virtual elements based on the user's in-app performance. The BPAS has been found to be safe (35), desirable (36), and tolerable (30) when used by people with ASD. The facial affective analytics component of BPAS was developed in partnership with Affectiva, an emotion artificial intelligence company. This work was also made possible by Google, Inc., now known as Alphabet, Inc., who provided substantial hardware and guidance in engineering. Brain Power, the company that developed the BPAS, has been a long-term Glass partner in the Glass Enterprise Partnership Program at X, a company of Alphabet, Inc.

Methods

The methods and procedures of this study were approved by Asentral, Inc., Institutional Review Board, an affiliate of the Commonwealth of Massachusetts Department of Public Health.

Eight children and adults with ASD signed up to take part in this research through a web-based research interest form (average age: 15 years, range 11.7 – 20.5; 7 males, 1 female). Participant demographics are summarized in Tables 1 and 2. Written consent was obtained from the legal guardians of children and from cognitively-abled adults. Participants between 7 and 17 years-old provided written assent, when they were able to.

All participants were questioned whether they had a past history of ADHD, and whether they were currently receiving treatment for ADHD. Additionally all participants had a baseline ABC-H and Social Communication Questionnaire (SCQ) (37).

The ABC-H is a subscale that has been utilized in published ADHD treatment studies in ASD (27, 28), and includes items that rate key ADHD symptoms such as inattention, impulsivity, and hyperactivity. Specifically, the ABC-H assesses inattention/impulsivity through items that require the rater to assess whether client is “easily distractible”, “does not pay attention to instructions”, “pays no attention when spoken to”, or is “impulsive”.

Following these baseline assessments, the participants were stratified into high and low ADHD symptom groups based on their baseline ABC-H score. Individuals with a score of 13 or higher were considered to have high ADHD symptoms (mean high ABC-H group score = 25.75), while those with a lower score were deemed as having low ADHD symptoms (mean low ABC-H group score = 5.5). Half of the participants had a history of ADHD (*n* = 4, 50%), three of whom were receiving active treatment at the time of testing. Of note, based on their ABC-H scores as above, two participants that were previously diagnosed with ADHD were categorized in the low ADHD symptom group, while the remaining two were categorized into the high ADHD symptom group. The ABC-H was used as a stratification method as it provided a numerical measure of recent (baseline) ADHD symptom burden. This numerical subscale allows for a more quantitative measure of change in rated items. While a clinical history of ADHD was obtained, the clinical diagnosis of ADHD in ASD is challenging (38), and it was only with the release of the DSM-5 (39) that it became possible to diagnose ADHD in an individual with ASD. Prior to the release of the DSM-5, the DSM-IV TR specifically excluded a diagnosis of ADHD being made when an individual had a diagnosis of ASD. Therefore, while background information regarding ADHD history was obtained, the ABC-H was the principal measure of stratification for this report.

All participants had a baseline SCQ (37) as a validated measure of their ASD symptoms. The SCQ score demonstrated that participants represented a wide range of social communication abilities, from 11 to 28 points (mean score 18).

All participants were accompanied by a caregiver to the testing session. The participants and their caregivers were oriented to the BPAS and Google Glass, and their ability to tolerate wearing the smartglasses was measured. Once the participants showed they were able to wear the smartglasses for at least one minute, the participants were able to use the BPAS social communication modules and had a series of gamified experiences while interacting with their caregiver. The BPAS modules help users to recognize and direct their attention towards socially salient stimuli such as human faces (in particular, the central part of the face, including eye regions), emotional facial expressions, and changes in social environment. Participants and caregivers were able to verbalize any concerns or difficulties in using the BPAS both during and immediately after the session. An ABC-H score was obtained at 24-hours and at 48-hours post session through the caregiver’s report. A clinically significant change in ABC-H was determined by a 25% or more change in the score, a standard that has previously been utilized (27).

Exclusions
Individuals who had expressed interest via the website signup but who had a known history of epilepsy or seizure disorder were not enrolled in this study. Users who had any uncontrolled or severe medical or mental health condition that would make participation in the study predictably hazardous were also not eligible for enrollment.

Results

All participants were able to use smartglasses and complete the coaching session .

The high ADHD-related symptom group had a similar ASD severity to the low ADHD-related symptom group (18.5 vs 17.6 SCQ score), but consistent of younger participants (12.5 vs 17.6 years).

ABC-H scores were lower post-intervention for most participants at 24 hours (*n* = 6, 75%), and for all participants at 48 hours (*n* = 8, 100%). At 24-hours post-session, average ABC-H scores decreased by 54.4% in high ADHD symptom group and by 20% in the low ADHD symptom group. At 48-hours post-session ABC-H scores compared to baseline decreased by 56.4% in the high ADHD symptom group and by 66.3% in the low ADHD symptom group.

The high ADHD-related symptom group consisted of four participants who demonstrated an average ABC-H score of 25.75 at the start of the study (Table 3). The high ADHD-related symptom group reported a reduction in average ABC-H score at 24-hours (ABC-H score: -12, -54.9% reduction from baseline) and at 48-hours post-session (-11.75, -56.4%). The low ADHD-related symptom group consisted of four participants who had an average ABC-H score of 5.5 at the start of the study (Table 4). The low ADHD-related symptom group had decreased average ABC-H score at 24-hours (-1, -20%) and 48-hours post-session (-3.5, 66.3%). The average reduction in ABC-H score for the high ADHD-related symptom group was greater than the low ADHD-related symptom group at both 24-hours (12 vs 1 point) and 48-hours (11.75 vs 3.5 points) post-session.

Table 3: High ADHD-related Symptom Groups and ABC-H Scores

Participant Identifier	ABC-H Score & Percentage Change Relative to Baseline				
	Baseline Score	*24 Hour Score*	*24 Hour % Change*	*48-Hour Score*	*48-Hour % Change*
1	17	1	-94.1	1	-94.1
2	48	40	-16.7	42	-12.5
3	24	3	-83.3	4	-79.2
4	14	11	-21.4%	9	-35.7%
Average	25.75	13.75	-54.9	14	-56.4

Table 4: Low ADHD-related Symptom Groups and ABC-H Scores

Participant Identifier	ABC-H Score & Percentage Change Relative to Baseline				
	Baseline Score	*24-Hour Score*	*24-Hour % Change*	*48-Hour Score*	*48-Hour % Change*
5	4	6	+50	1	-75
6	5	5	0	4	-20
7	10	7	-30	3	-70
8	3	0	-100	0	-100

Average	5.5	4.5	-20	2	-66.3

Discussion

Many people with ASD struggle with symptoms of ADHD, including hyperactivity, impulsivity, and inattention. This report provides preliminary findings for a reduction in ADHD-related symptoms in children and adults with ASD following use of a smartglasses-based social communication aid. All of the participants managed to complete the testing session without any reported negative effects, and all participants tolerated using smartglasses for the duration of the testing session. Improved ADHD-related symptoms were noted by most participants at 24 hours post-session (*n* = 6, 75%), and by all participants at 48 hours (*n* = 8, 100%). These results provide preliminary evidence that BPAS did not cause hyperactivity symptoms to worsen in this group.

While participants were divided into high and low ADHD-related symptom groups, the high ADHD-related symptoms group was younger, but had a similar autism symptom severity as measured by the SCQ. It is perhaps not a surprise to find that the high symptom group was younger given that the ABC-H subscale is weighted towards hyperactivity, and that hyperactivity is an ADHD-symptom that improves with age (40).

The high ADHD-related symptom group demonstrated a clinically significant response (greater than 25% improvement in ABC-H score) at both 24- and 48-hours (-54.9% and -56.4%, respectively). The low ADHD-related symptom group appears to have demonstrated a response at 48-hours (-66.3%), but not at 24-hours (-20%). The authors, who include a subspecialist child psychiatrist, believe that in the low ADHD-related symptom group, the low baseline score (and therefore the small margin for reduction in ABC-H scores) may render the ABC-H changes in this group to be clinically insignificant. This assertion would benefit from further study of this technology. These results provide preliminary evidence that the BPAS may reduce symptoms of hyperactivity in people with ASD who have considerable hyperactivity symptoms at baseline. This finding is important given the concerns that new technologies may worsen attention, and prove to be a distraction in individuals of school/college age.

There are a number of important limitations to this work that deserve mention. Firstly, the number of children and adults in this report was relatively small (*n* = 8), although a sizeable sample relative to other research on novel technologies in ASD, especially in regard to other smartglasses research (30, 41). This report can hopefully pave the way for more funding and interest to study the potential application of this technology to this population. It would, however, be useful for future research to incorporate a larger sample size, with more female participants. One can also see the benefit of age-matched neurotypical and ADHD-only controls. While the ABC-H is a very useful scale to use in this context, the use of broader ADHD-related measures would also provide for further insights. Despite our findings, the broader generalizability of our results to the wider ASD population will remain limited until further research is undertaken.

We should certainly consider the potential for a placebo effect in using this technology, especially given that the testing session was a novel experience for both the participant and the caregiver. However, the potential for a placebo effect should also be tempered by our knowledge that transitions or new experiences have been associated with extreme distress in people with ASD, so much so that it is a characteristic part of diagnosis (39). We noted that none of the participants encountered any noticeable distress or problems with using the smartglasses.

Overall the findings suggest that this type of technology is usable, and may result in changes to ADHD-related symptoms, such as hyperactivity, inattention, and impulsivity, in school-aged children and young adults with ASD. Smartglasses like the BPAS contain a wide variety of quantitative sensors that are being used to help understand human behavior, and further funding is warranted to study these emerging technologies.

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