**Preliminary Report on the Impact of Smartglasses-based Behavioral and Social Communication Aid on Hyperactivity in Children and Adults with Autism.**

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**ABSTRACT**

**Introduction**

People with autism spectrum disorder (ASD) commonly experience symptoms of hyperactivity, inattention, and impulsivity, and a third of people on the spectrum may be diagnosed with attention hyperactivity deficit disorder (ADHD). These individuals often face barriers to having their ADHD symptoms treated. 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 impact on hyperactivity 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 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) determined their classification into a high ADHD symptom group ($n = 4$, ABC-H $\geq 13$) and a low ADHD symptom group ($n = 4$, ABC-H $< 13$). All participants attended a coaching session with BPAS, where they used BPAS social communication and behavioral apps while interacting with their caregiver. Caregiver-reported ABC-H scores were calculated at 24- and 48-hours post-session.

**Results**

Mean ABC-H scores were lower in both low and high ADHD groups at 24- and 48-hours post-session. 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**

BPAS, a novel smartglasses-based behavioral and social communication aid for children and adults with ASD, was associated with reduced short-term symptoms of hyperactivity. While on the one hand, there may be a placebo effect to novel technology, on the other hand, people with ASD may react negatively to transitions or new experiences. The 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, with approximately one-third of people with ASD being 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 even 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 both ASD and ADHD have been found to be less likely to receive appropriate treatment of 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 around concerns regarding 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). Little research has described the impact of digital interventions on people with ASD who demonstrate ADHD symptoms (20). 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 (21). We have previously described the delivery of social communication coaching on augmented reality smartglasses via the Brain Power Autism System (BPAS) (22). Our report on two boys with ASD demonstrated short-term improvements in the hyperactivity subscale of the the aberrant behavioral checklist (ABC-H) (22), a validated instrument that assesses hyperactivity, impulsivity, attention, and non-compliance (23). The ABC-H has previously been used as a primary outcome measure in ADHD treatment studies in children with ASD (24, 25).

**The Brain Power Autism System (BPAS)**

BPAS teaches social communication and cognitive skills through the use of gamified apps, an approach that may be particularly valuable to both people with ASD (26) and people with ADHD (27, 28). BPAS has specific apps that run on smartglasses, and help users to coach themselves to attend to socially salient stimuli, such as human faces and facial emotions. 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 also 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 (29), acceptable (30) , and tolerable (31) when used by children and adults with ASD. The facial affective analytics component of BPAS was developed in partnership with Affectiva, an emotion artificial intelligence company. The work was also made possible by Google, Inc., now known as Alphabet, Inc., who provided substantial hardware and well as 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, formerly known as Google, 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 Table 1. Written consent was obtained from the legal guardians of children and from cognitively-able adults. Participants between 7 and 17 years-old provided written assent, when possible.

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 entered

were considered as having high ADHD symptoms (mean ABC-H group score = 25.75), while those with a lower score were deemed as having low ADHD symptoms (mean 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.

All participants had a baseline Social Communication Questionnaire (32) as a measure of their ASD symptoms. The Social Communication Questionnaire 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 orientated to BPAS, and their ability to tolerate wearing the smartglasses was measured. The participants then used BPAS social communication apps and had a series of gamified experiences while interacting with their caregiver. BPAS apps 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 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 (24).

| Table 1: Participant Demographics | | |
|---|---|---|
| **Number of users** | 8 | |
| **Age (mean ± SD)** | 15 ± 3.4 | Range = 11.7 – 20.5 years |
| **Participant gender** | Male: 7 (87.5%) | Female: 1 (12.5%) |
| **Prior ADHD diagnosis** | Yes: 4 (50%) | No: 4 (50%) |
| **ADHD treatment during study** | Yes: 3 | No: 5 |
| **Social Communication Questionnaire (SCQ) Score (mean ± SD)** | 18.1 ± 5.8 | Range: 11 – 28 |

**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 BPAS based on verbal reporting during session and post-session survey responses. The high ADHD symptom group consisted of four participants who demonstrated an average ABC-H score of 25.75 at the start of the study (Table 2). The high ADHD 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 symptom group consisted of four participants who had an average ABC-H score of 5.5 at the start of the study (Table 3). The low ADHD 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 symptom group was greater than the low ADHD symptom group at both 24-hours (12 vs 1 point) and 48-hours (11.75 vs 3.5 points) post-session.

**Table 2: High ADHD 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 3: Low ADHD 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 evidence of a reduction in hyperactivity symptoms in children and adults with ASD following use of a novel 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. Out of the 16 different post-session ABC-H scores documented for the 8 participants, it is somewhat reassuring that 15 ABC-H scores were lower than baseline, and that the 1 ABC-H score that was initially higher than baseline at 24-hours, was lower than baseline at 48-hours. These results provide preliminary evidence that BPAS did not cause hyperactivity symptoms to worsen in this group.

The high ADHD 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 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 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 not to be clinically noticeable. 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.

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 it is a sizeable sample for research on novel technologies in ASD. It would be useful to have a larger sample size, ideally with neurotypical and ADHD-only controls, to further understand the reduction in hyperactivity that has been described. Additionally, it would be useful to have a greater number of outcome measures that could better cover the other symptoms of ADHD (e.g. inattention). The generalizability to the results to the wider ASD population, people with other conditions, or to non-clinical populations is unknown, and further research is necessary.

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 (33).

Overall the findings suggest that this type of technology is usable, and may result in changes to behavior, such as hyperactivity, in a wide range of children and adults with ASD. Smartglasses like BPAS contain a wide variety of quantitative sensors that are being used to help understand human behavior, and further research is warranted on these emerging technologies.

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