# HFS Hope Focus System: Pilot data from an intelligent, integrative intervention for neurodiverse children

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# 1. Introduction

## 1.1 ASD & ADHD neurological underpinnings

ASD and ADHD share common neurological features that impact cognitive and emotional functioning in children (Watanabe & Watanabe, 2023). Key brain systems implicated include the **fronto-striatal dopaminergic circuitry** that affects emotional, associative and motor systems, as well as the **cerebro-cerebellar circuits** linked to cognitive and motor functions (Grimm et al., 2021). Both systems show decreased activity or reduced cortical volume in both conditions (Willsey et al., 2022). Disruptions in the **vestibular system** contribute further to motor coordination and balance challenges (Djordjević et al., 2022), while cortical divergences such as asymmetrical auditory and language circuitry processing leads to sensory gating and speech processing challenges (Liu et al., 2021).

## 1.2 HFS: Holistic intervention targeting neuropathology

Hope Focus System (HFS) is a holistic and intelligent intervention for ADHD and ASD children (ages 5-18) that addresses shortcomings of traditional interventions. Combining AI with a humanistic approach, HFS's targets underlying neurological factors by integrating three therapeutic elements:

**1. Strength-based therapeutic connection**
**2. Music and auditory processing stimulation**
**3. Skill-based exercise therapy**

Each element is balanced session-to-session through AI-assisted customization. By leveraging the brain's plasticity during critical developmental years, HFS aims to maximize engagement and motivation while maintaining consistent skill development.

### 1.3.1 HFS Coach: Building Therapeutic Connection and Acceptance

A strong therapeutic relationship is crucial for effective interventions in ADHD and ASD, as it fosters emotional regulation, social skills, and a sense of safety, ultimately enhancing the overall efficacy of treatment. HFS Coaches undergo Cogleap's APA-accredited training and implement child-centered behavioral therapy following the **5-step Cycle of Excellence** framework developed specifically for neurodiverse children (Hallowell, 1995).


**Figure 1.** 5-Step Cycle of Success: Strength-based and child-centered behavioral therapy framework developed especially for neurodiverse children. The five steps are: 1. Building connection and trust with children, 2. Introducing elements of play into therapy, 3. Aiding neurodiverse children to practice skills, 4. Mastery of small and attainable steps, and 5. Recognition of the child's effort and growth.

### 1.3.2 Auditory Processing Intervention via Music Listening Therapy

Music-based interventions can enhance social skills, communication, and emotional regulation in neurodiverse children by engaging in neural networks related to auditory and language processing (Zhang, 2023). HFS delivers music with frequency band filtration at different timepoints; this selective frequency filtration targets the auditory system's tonotopic map with projections to language processing regions. HFS also utilizes bone-conduction headphones for direct vestibular stimulation while maintaining an open outer ear canal.

### 1.3.3 Skill-Based Exercise as a Therapeutic Intervention

Moderate-intensity exercise is beneficial for children with ADHD and ASD, leading to significant improvements in cognitive, behavioral, and social-emotional

Functioning (Ye et al., 2023). HFS incorporates 9 categories of skill-based exercises that each target specific cortical functions implicated in neurodiverse conditions:

1. **Breathing**
2. **Balance**
3. **Core Strength**
4. **Hand-Eye Coordination**
5. **Crossing Midline**
6. **Body Coordination**
7. **Dexterity**
8. **Flexibility**
9. **Aerobic Endurance**

**Figure 2.** Screenshot examples from video references of HFS's skill-based exercise therapy activities, composed of 9 skill categories with 100 exercises per category, divided into 20 difficulty levels based on developmental suitability, physical strength required, and complexity of movement. Each of the 9 categories target different motor and behavioral skills that exert bottom-up effects on higher cortical functioning that are often challenged in neurodiverse children.

# 2. Methods

## 2.1 Participants

A total of 58 participants (26 females, mean age 9.3 yrs) were included in this pilot study to examine the effects of HFS intervention for children with neurodiverse conditions. Real-world pilot data was obtained from Cogleap US's Irvine, CA and Palo Alto, CA clinics. All participants engaged in at least 24 total sessions for a total duration of 3 months, with a varying frequency of 1-3 sessions per week, at 60-minutes per session.

| Diagnosis | No. of Clients | % |
|---|---|---|
| ADHD | 6 | 10% |
| Autism | 10 | 17% |
| Comorbid ADHD+Autism | 2 | 3% |
| Other NDDs | 6 | 10% |
| No formal diagnosis | 34 | 59% |
| **Total** | **58** | |

**Table 1.** Diagnosis statuses for the total study sample. Inclusion criteria: children / adolescents between ages 5-18,) having a

diagnosis of ADHD, ASD, or related neurodevelopmental symptoms, no other comorbid conditions, global developmental delay, or intellectual and physical disabilities.

## 2.2 Intervention protocol

All participants upon intake were interviewed about their medical history, and completed the Fundamental Abilities Survey (FAS), based on the Five-to-Fifteen parent rating questionnaire, measuring behavioral subdomains. The FAS scores are used to determine the initial music stimulation protocol. Each child is assigned their personal HFS coach, who guides and delivers the exercise therapy per session while the child simultaneously undergoes music listening therapy via bone conduction headphones. Exercise categories and difficulty levels are adjusted per session and intelligently customized based on a propriety algorithm.

Participants's cognitive and motor attention skills were also assessed using the vCAT (Virtual Classroom Attention Test, see Fig. 3), a VR-based diagnostic aid for attention disorders (Goh et al., 2024). The vCAT uses real-time behavioral and motion data-tracking in a VR continuous performance test (CPT) that is able to determine an individual's attention skill compared to a normative database (ages 6-13).


**Figure 3.** Virtual Classroom Attention Test: a virtual reality assessment that measures cognitive and motor attention variables corresponding to Inattention and Hyperactivity/Impulsivity traits.

At the end of the 3 month period, participants were again tested on the FAS and the vCAT to determine pre- and post-intervention differences across cognitive and behavioral domains. Of the total dataset of 58 participants, 11 and 21 participants fulfilled all criteria for the FAS and vCAT measurements respectively.

## 2.3 Variables measured

FAS measurements included 13 subdomain scores. vCAT measures included 5 CPT scores and 5 motion signal variables.

### 2.3.1 FAS subdomains

FAS is derived from the Five-to-fifteen-revised (5-15R) parent rating scale. The original 5-15R contains 24 subdomains, of which 13 are included in HFS:

1. Gross motor skills
2. Fine motor skills
3. Attention and concentration
4. Hyperactivity and impulsivity
5. Planning/organizing
6. Time concepts
7. Sensory Processing
8. Emotional Regulation
9. Memory
10. Social Skills
11. Language Processing
12. Expressive Language Skills
13. Verbal Communication

### 2.3.2 vCAT CPT scores

***Omission errors***

Number of errors where the participant fails to respond to the target stimulus as required. Omission errors are indicative of challenges in selective and focused attention, and freedom from distractibility.

***Commission errors***

Number of errors where the participant makes a “hit” response in the absence of a target stimulus. These errors reflect deficiencies in motor control or response inhibition.

***Accuracy (%)***

Percentage of correct responses to both the targets and the non-targets, as a measure of general performance combining focused and sustained attention.

***Latency (ms)***

The average reaction time (ms) to correctly respond to a target, measured across all correct responses.

***D-prime***

D-prime measures the participant’s ability to discriminate between signal and noise. It is calculated as a Z-score, providing a standardized metric for signal detection.

### 2.3.3 vCAT motion scores

***Immobility duration (ms)***

The average time (ms) spent sitting still (not moving head more than 1 mm in virtual space) as a measure of physical stillness. The longer the Immobility Duration, the less movements the participant made during the 13-min test.

***Movements***

The number of head movements (more than 1 mm in virtual space) as a measure of the number of large magnitude movements. The number or count of movements indicates how frequently the participant is moving across the 13-min test.

***Total displacement (cm)***

The cumulative length (cm) that the head moved over the 13 min, as a measure of the total amount of movement that was made across the test period. A participant making large movements but infrequently will have a relatively smaller Total Displacement outcome. A participant making small to medium movements but frequently will end up with a relatively larger Total Displacement outcome.

***Area ($m^2$)***

The total spatial area (expressed in $m^2$ in 2D space) that is covered by the path of head movement, as a measure of the spatial range of movement. A larger number indicates the participant's range of movement in space is bigger, and a smaller area indicates that the participant's range of movement in space is smaller.

***Time at board (min)***

Cumulative time (in minutes) spent facing towards the whiteboard and CPT task, as a measure of sustained attention and stillness. A higher score for Time At Board means the participant spent more time in minutes with their head facing directly towards the whiteboard. A lower score indicates the participant spent more time looking away from the board.

# 3. Results

## 3.1 HFS improves behavioral and cognitive skills

After an average of **40 HFS sessions**, participants showed significant improvement in the following FAS domains: **Emotional Regulation** ($T(10)= -2.57$, $p<.05$); **Attention & Focus** ($T(10)= -2.84$, $p<.05$); **Impulsivity & Hyperactivity** ($T(10)= -3.19$, $p<.05$); **Concept of Time** ($T(10)= -2.84$, $p<.05$); **Planning & Organization** ($T(10)= -2.52$, $p<.05$); **Language Comprehension** ($T(10)= -2.49$, $p<.05$); **Language Expression** ($T(10)= -2.95$, $p<.05$). All

other FAS domains showed a trend in skill improvement after HFS training as well (see Figure 4).

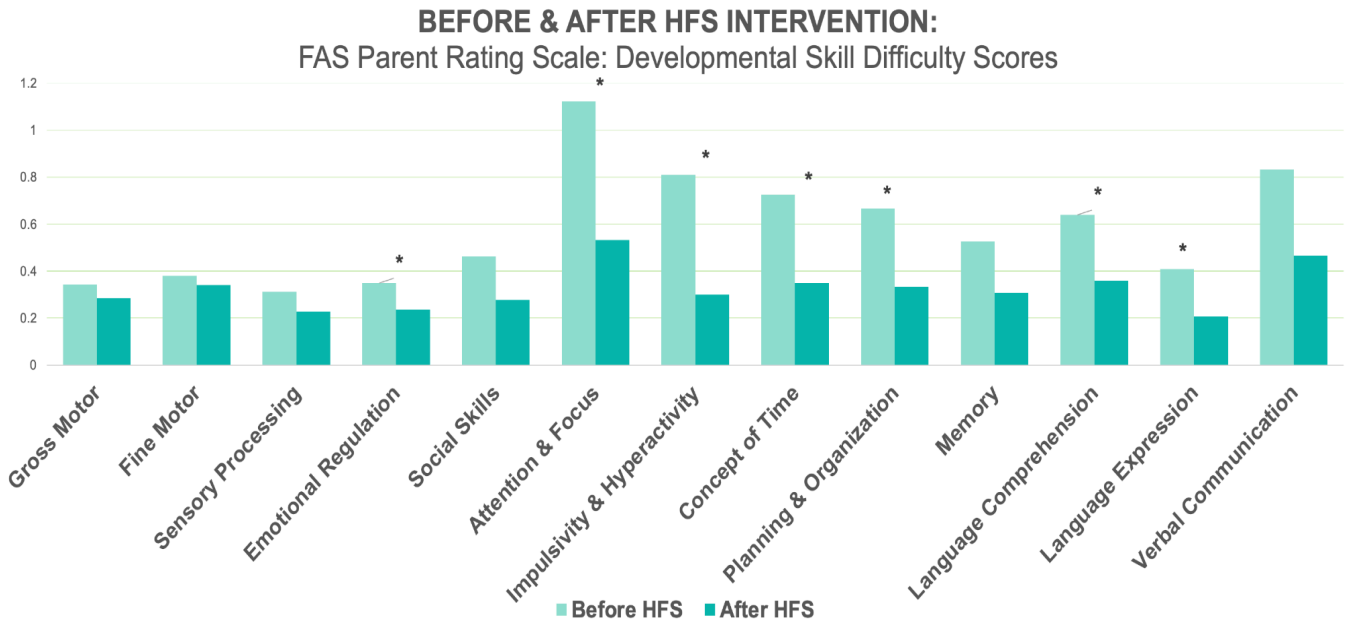


**Figure 4.** FAS scores before and after HFS intervention. *: p<.05*

## 3.2 HFS improves inattention and hyperactivity / impulsivity

After an average of **50 HFS sessions**, participants showed significant improvement in all vCAT attention measures. Specifically, an average of 50 HFS sessions **reduces errors of attention** (See Figure 5a., vCAT CPT measures of *Omission Errors* ($T(20)= -4.69$, $p<.001$); *Commission Errors* ($T(20)= -4.33$, $p<.001$)) and **reduces hyperactivity and impulsivity** measures (See Figure 5d., vCAT motor measures of *No. of Movements* ($T(20)= -3.48$, $p<.01$); *Total Displacement* (distance) ($T(20)= -3.37$, $p<.01$); *Area of Movement* ($T(20)= -2.79$, $p<.05$)).

An average of 50 hour of HFS also **improved focus and accuracy** (see Figure 5b., vCAT CPT measures of (Attention) *Continuity* ($T(20)= 4.67$, $p<.001$); *Signal Detection* ($T(20)= 10.31$, $p<.001$); *Accuracy* ($T(20)= 5.60$, $p<.001$)), as well as i**mproved physical control of stillness and stability** (see Figure 5c., vCAT motor measures of *Immobility Duration* ($T(20)= 3.55$, $p<.01$); *Time at Board* ($T(20)= 3.49$, $p<.01$)).

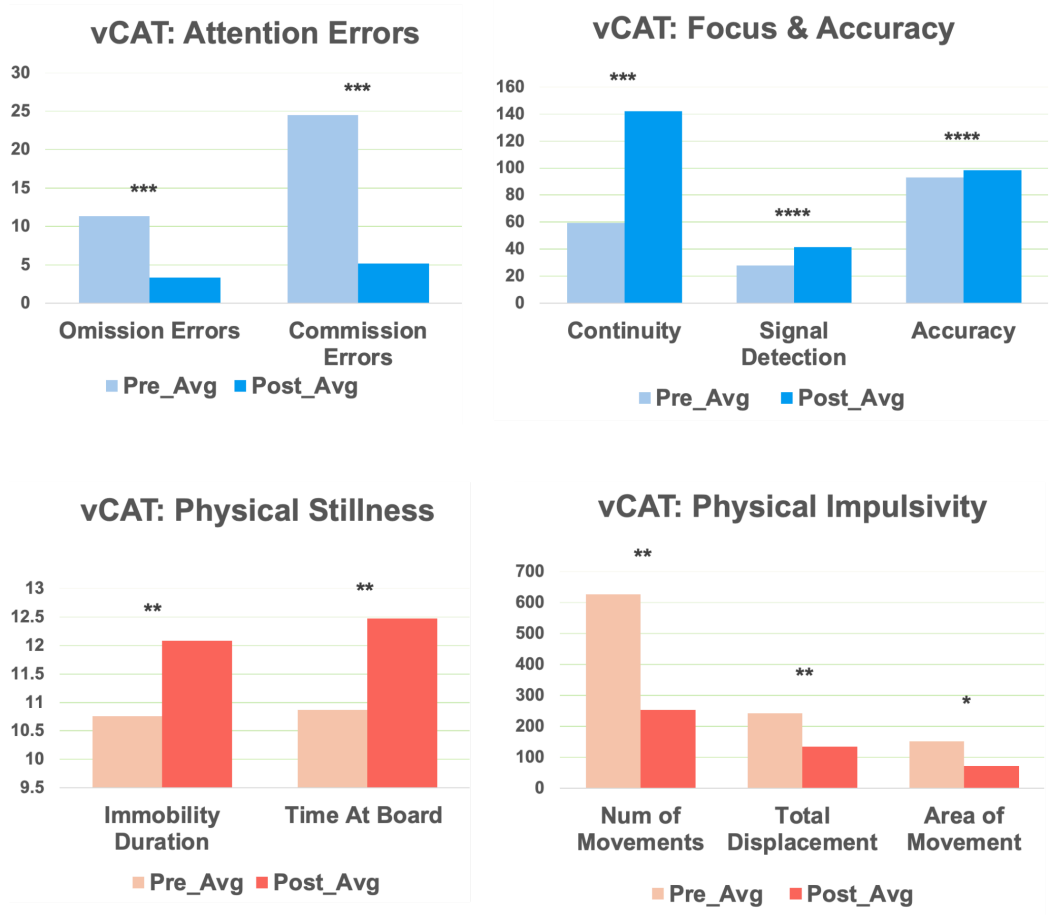


**Figure 5a-b.** vCAT measurements before and after HFS intervention. *: p<.05; :p<.01; :p<.001; :p<.0001.*

# 4. Discussion & Conclusions

## 4.1 Summary of Key Points

HFS was highly effective in improving cognitive and motor attention in children with ADHD and ASD. Key findings were:

1. After an average of 40 HFS session hours, more than half of the FAS subdomains showed significant improvement after HFS intervention, and
2. All remaining FAS subdomains showed a trend of improvement.
3. All vCAT attention assessment measures showed improvement after an average of 50 HFS session hours, including tests of sustained attention, selective attention, and attentional control.

Overall, the HFS program was successful in enhancing both core cognitive, behavioral, and specifically attentional processes that are often impaired in both ASD and ADHD.

## 4.2 Therapeutic elements of HFS individually and in combination

Music Listening Therapy: HFS's music stimulation therapy is aimed at activating brain areas linked to hearing, attention, and emotions via tonotopic map stimulation in the auditory system. This is targeted at the commonly observed sensory gating, language and communication challenges that especially children with ASD experience.

Exercise Therapy: Skill-based exercises in HFS are designed to boost prefrontal cortex function, enhancing executive control and attention. Participants showed significant gains in postural stability, fine motor control, and visuomotor integration after the HFS intervention, resulting in better coordination and focus. Exercise stimulates the cerebellum, which helps improve coordination with the prefrontal cortex. This stimulation can address cognitive and social-emotional challenges in ADHD and ASD by enhancing the connections between brain regions. The psychomotor mechanisms are also aimed at enhancing attention and awareness of bodily sensations, while increasing levels of BDNF to improve neuroplasticity and support neural growth in ADHD and ASD children. Physical activity also boosts neurotransmitter release, particularly dopamine and serotonin, mimicking the effects of stimulant medications. Mindful movement practices further enhance these effects, improving attention and emotional regulation.

Therapeutic Relationship: The supportive coaching in HFS based on the Cycle of Excellence further fosters strong relationships and emotional regulation for neurodiverse children. This support may reduce anxiety and improve self-control, helping participants focus better during tasks.

AI-assisted Customization: HFS's intelligent system helps to maintain step-by-step improvement because each session is titrated to balance engagement with the right level of challenge.

## 4.3 Implications for Practice & Future Directions

The premise of HFS is to target neuropathology of ASD and ADHD, integrating multiple therapeutic elements at once in a precise manner that is customized and intelligently calculated with an AI-assisted system, while delivered with HFS coaches to maintain human-centered therapeutic connection.

The success of the current pilot study underlines the importance of recognizing that intervention for neurodiverse children and adolescents require many different components, whose efficacy and efficiency of intervention delivery can be optimized using technology.

The current pilot study also lays the foundation for future research such as a well-controlled randomized clinical trial. Future explorations should consider measuring the efficacy from a higher dimension of markers, as well as exploring how different baselines and diagnoses behave under the system.

# 5. References

Djordjević, M., Memisevic, H., Potic, S. & Djuric, U. (2022). Exercise-Based Interventions Aimed at Improving Balance in Children with Autism Spectrum Disorder: A Meta-Analysis. Perceptual and Motor Skills, 129(1), 90–119. https://doi.org/10.1177/00315125211060231

Goh, C., Ma, Y. & Rizzo, A. (2024) Normative performance data on visual attention in neurotypical children: virtual reality assessment of cognitive and psychomotor development. Front. Virtual Real. 5, 1309176

Grimm, O., Rooij, D. van, Hoogman, M., Klein, M., Buitelaar, J., Franke, B., Reif, A. & Plichta, M. M. (2021). Transdiagnostic neuroimaging of reward system phenotypes in ADHD and comorbid disorders. Neuroscience & Biobehavioral Reviews, 128, 165–181. https://doi.org/10.1016/j.neubiorev.2021.06.025

Hallowell, E. M. (1995). Driven to distraction: recognizing and coping with attention deficit disorder from childhood through adulthood. 1st Touchstone ed. New York, Simon & Schuster.

Liu, M., Li, B. & Hu, D. (2021). Autism Spectrum Disorder Studies Using fMRI Data and Machine Learning: A Review. Frontiers in Neuroscience, 15, 697870. https://doi.org/10.3389/fnins.2021.697870

Watanabe, D., & Watanabe, T. (2023). Distinct Frontoparietal Brain Dynamics Underlying the Co-Occurrence of Autism and ADHD. eNeuro, 10(7), ENEURO.0146-23.2023. https://doi.org/10.1523/ENEURO.0146-23.2023

Willsey, H. R., Willsey, A. J., Wang, B. & State, M. W. (2022). Genomics, convergent neuroscience and progress in understanding autism spectrum disorder. Nature Reviews Neuroscience, 23(6), 323–341. https://doi.org/10.1038/s41583-022-00576-7

Ye, Y., Ning, K., Wan, B. & Shangguan, C. (2023) The Effects of the Exercise Intervention on Fundamental Movement Skills in Children with Attention Deficit Hyperactivity Disorder and/or Autism Spectrum Disorder: A Meta-Analysis. Sustainability 15, 5206

Zhang, T. (2023) Review of Randomised Controlled Trials on the Effect of Music Therapy on Autism. J. Educ., Humanit. Soc. Sci. 8, 2520–2524