Patterns of Resting Cerebral Blood Flow in Autism Spectrum Disorder Associated with Sensory-Motor Dysfunction, ADHD, and Autistic Features

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Abstract

Neurological soft symptoms, motor difficulties, hyperactivity, and inattention characterize autism spectrum illnesses. These symptoms are linked to patterns of regional cerebral blood flow (rCBF) during rest. Nonetheless, the links are not obvious. A PET scanner was utilized to study 133 patients with ASD and 10 healthy controls with properly developing brains. In a factorial experiment, regional cerebral blood flow (rCBF) was shown to connect with autism, attention deficit hyperactivity disorder (ADHD), and neurological soft symptoms. We looked at the parameters linked with "autistic/ADHD characteristics," "sensory-motor integration," and "cognitive/motor sequencing" separately. Brain regions associated with "autistic/ADHD traits" (in the bilateral caudate and inferior parietal lobule), "sensory-motor integration" (in the parieto-occipital cortex), and "intelligence/motor sequencing" (in the right temporal lobe) have a positive correlation with cerebral blood flow in people with ASD. All three parameters negatively correlated blood flow to the left thalamus and cerebral cortex. Autism and attention deficit hyperactivity disorder (ADHD) have underlying brain connections. The link between "autistic/ADHD traits" and regional cerebral blood flow in the caudate nucleus might explain the executive dysfunctions and repetitive or stereotyped behaviors seen in ASD. A song's relationship with the aberrant visual perception seen in Autism Spectrum Disorder (ASD) connects the occipital visual cortex to sensory-motor problems and regional cerebral blood flow. Autism spectrum disorder (ASD) is thought to be characterized by a convergence of behavioral and neurological features.

Keywords

Cerebral Blood Flow (rCBF), Autism Spectrum Disorders (ASD), Sensory-Motor Integration

1. Introduction

[1] Examine the possibility of sensory-motor impairments that are relevant to the spectrum of ASD phenotypes and that are associated with symptoms that characterize ADHD. Some of the challenges individuals diagnosed with autism spectrum disorder possess and sustaining relationships, difficulty communicating, and participation in activities that do not encourage the exploration of other viewpoints. Impulsivity, hyperactivity, and inattention are hallmarks of the complex diagnosis known as Attention Deficit/Hyperactivity Disorder. A patient diagnosed with ASD cannot be given the ADHD diagnosis according to the DSM-IV criteria (American Psychiatric Association, 1994; [2]. Clinical research [3] as well as population-based [2] have indicated the co-occurrence of ASD and ADHD symptoms. Research shows that between 20 to 80 percent of children identified with ASD exhibit signs of ADHD [4]. Symptoms of ADHD persist all through adulthood [5], and the degree of ASD seems to match the presence of ADHD symptoms [6]. A good number of children diagnosed with ADHD also fit the ASD criteria [7]. Since no one test or neurophysiological evaluation has enough accuracy, an accurate diagnosis of ASD calls for the study of various facets of the condition [8].

Neurological soft symptoms in Attention Deficit Hyperactivity Disorder (ADHD) and Autism Spectrum Disorder (ASD) include delicate difficulties with sensory integration, motor coordination, and the sequencing of complicated motor activities. Concurrent motor abnormalities with Attention Deficit/Hyperactivity Disorder have been related to a greater incidence of autistic symptoms than ADHD alone, and motor dysfunction may develop before language and social deficits in Autism Spectrum Disorder [9]. Research has shown that motor signals are not well integrated with sensory data, supporting the idea that ASD is associated with dysfunction in the cerebellum and thalamus [10].

Psychiatric samples include schizophrenia [11]; A condition known as Obsessive-Compulsive Disorder. A systematic instrument for assessing neurological soft signals is the Neurological Evaluation Scale (NES). The NES scores of patient cohorts were consistently higher than healthy controls across all assessments. Reduced grey matter was also linked to structural correlates of neurological soft symptoms in both healthy individuals and psychotic patients [12].

Neuroimaging studies investigating the brain correlates in ASD have been few and far between, with most studies concentrating on children and adolescents and using direct comparisons between ADHD patients and neurotypical controls (NC). Brain scans taken from the medial temporal lobe and inferior parietal cortex showed connections to hyperactivity, autism spectrum disorder, and inattention [13]. In addition, there was an increase in white matter volume

in the left primary motor and premotor cortex, which was related to worse motor abilities in autistic children when compared to children with ADHD and healthy controls [14]. These studies imply that structural alterations in ASD are probably going to interfere with functional connections and influence motor and cognitive performance.

In several positron emission tomography (PET) investigations on autism spectrum disorder (ASD), specific metabolic alterations have been detected in different subcortical and cortical areas [15]. However, studies examining cerebral glucose metabolism (rCMRgl) and regional cerebral blood flow (rCBF) have not shown consistent regional abnormalities. This might be because individuals with ASD vary in their symptoms and the varied approaches used by various researchers. Therefore, further research is required to identify the neurological components of ASD. We compared neurotypical people to adults with ASD in an earlier study. Our findings of increased regional cerebral blood flow (rCBF) in the right hemisphere's posterior area corroborate the involvement of both the cortex and the sub cortex in the disease's outward expression [16].

This study examines neurological soft indications that may be associated with ADHD, ASD, or both disorders using the same sample of participants. We postulated that the temporal-parietal-occipital areas of the brain, which have been linked to autism spectrum disorder (ASD) in the past, would correlate with the neural bases of autistic features, ADHD symptoms, and neurological soft indicators.

2. Method

2.1 Participants

Thirteen normally developing adults and adolescents with Autism Spectrum Disorder were examined alongside ten neurotypical controls matched for age, gender, and IQ. Intellectual handicaps, brain injury, epilepsy, epilepsy, alcoholism, drug addiction, psychosis, and any history of seizures were all grounds for exclusion from the study. [17] To be disqualified, NCs had to have a history of mental or personality problems, be currently on psychotropic medication, or have a first-degree family with a psychiatric disease. You can see the demographics and descriptive data in Table 1.

Table 1. Comparison of demographic and clinical features of neurotypical controls and people with ASD

Indicators	***ASD***	**Cont.**	***p−Value***
	***n* = 12**	***n* = 11**	
Age: Years	31.9 (8.7)	28.6 (7.6)	0.34
Male: female	7:7	5:4	0.84
Full scale IQ	104.3 (17.2)	115.8 (10.9)	0.09
Verbal intelligence	105.4 (16.5)	114.7 (13.1)	0.177
Ability Quotient	101.6 (17.7)	114.1 (9.8)	0.065
Handedness, *right*: *left*	12:2	9:2	0.84
Education			
<9 *years*, *n*	3	0	
8–11 *years*, *n*	3	4	
>12 *years*, *n*	4	6	
University degree, *n*	0	1	
Civil status, *single*: *cohabit*	12:2	6:5	0.05
Have children, *yes*: *no*	0:14	3:6	0.01
Independent living, *yes*: *no*	11:3	10:0	
At my full−time job/studies, *yes*: *no*	3:9	10:0	<0.0001
Nicotine use, *yes*: *no*	3:8[a]	2:9	0.96
Global assessment of functioning, total	53 (6.4)	83 (6.3)	<0.0001
Symptom-GAF	52.8 (5.7)	86.9 (5.1)	<0.0001
Function-GAF	55.4 (7.1)	91.8 (4.2)	<0.0001
Whole Ritvo Autism Asperger Syndrome Rating Scale, updated	108.6 (27.6)	18.5 (13.8)	<0.0001
Adult ADHD Self-Report Scale, comprehensive	33.1 (11.5)	17.5 (6.1)	0.003
Inattention	19.5 (7.3)	12.1 (4.3)	0.008
Hyperactivity/impulsivity	15.6 (8.1)	7.5 (2.3)	0.010
Scale for Rating Wender in Utah, total	56.8 (41.4)	10.4 (6.2)	0.001
Neurological Assessment Tool, comprehensive	14 (7.5)	5 (3.0)	<0.001

The standard deviation, which stands for the average values, is shown in parentheses. ASRs refer to the Adult ADHD Self-Report Scale, IQ stands for intellectual quotient, and GAF stands for global assessment of functioning.

2.1.1 Typical Brain Samples

12 Stockholm region participants stood sought for the NC research. One participant decided to drop out, while another was eliminated because of a first-degree relative with ASD [18].

2.1.2 Individuals with ASD

For this study, we reached out to 357 people who were already enrolled in the adult ASD community-based unit and to patients with ASD who were seen at the neuropsychiatric section of the mental clinic in Northern Stockholm.[19] Twenty people were interviewed out of fifty-five who were diagnosed with ASD and gave their agreement to participate. Seven individuals were recruited from the community, and two were eliminated from the study because of seizure activity or a history of drug misuse. Additionally, five individuals were unable to undergo the PET scan. The final choice was affected by the intended gender breakdown. All but one of the Asian-descended individuals were of Caucasian heritage.

A series of neuropsychiatric evaluations, including interviews, rating scales, neuropsychological examinations, and parental consultations, were conducted for all children identified with autism spectrum disorder. Eleven people were found to have Asperger's syndrome, and two were found to have high-functioning autism, according to the DSM-IV. Using the Autism Diagnostic Observation Schedule (ADOS), SB, one of the authors, verified the clinical diagnosis of Autism Spectrum Disorder (ASD). Based on Wing's account, two other writers who are skilled in diagnosing ASD, SB, and IM, both agreed that the subject had a social style [20]. " Strange, alone, and disparate, nine of them were deemed "active-odd." Adults on the autistic spectrum do not fit the "passive" or "rigid formal" profiles. Six of the people who met the diagnostic criteria for eight additional mental disorders—agoraphobia, bulimia Nervosa, major depressive disorder, dysthymic disorder, generalized anxiety disorder, obsessive-compulsive disorder, panic disorder, and social phobia—were also taking psychotropic medication.

2.2 Psychological and Psychiatric Evaluations

Discussing Axis-I illness in an interview [21], The Structured Clinical Interview for DSM-IV-R Personality issues (SCID-II) and the Structured Clinical Interview for DSM-IV-Axis I Disorders (SCID-I) were administered to neurotypical persons to identify potential mental health issues. The Mini International Neuropsychiatric Interview (M.I.N.I., version 5.00) was performed on individuals with Autism Spectrum Disorder (ASD) as part of a semi-structured interview aimed at investigating past mental health difficulties. The American Psychiatric Association's 1994 DSM-IV Global Assessment of Functioning is a great tool when gauging functional capability and total clinical impairment. Wechsler Adult Intelligence Scale-Revised (WAIS-III-R) was used by the researchers to monitor IQ. Subjects covered in the semi-structured interview included the following: marital status, education level, occupation, family history of mental illness, medical history (both current and previous), and health problems (current and past).

2.2.1 Neuropsychiatric Assessments

A standardized semi-structured evaluation known as the Autism Diagnostic Observation Schedule (ADOS) Module 4 verified the existence of Autism Spectrum Disorder (ASD). The ADOS has four components, each evaluating specific aspects: limited interests, stereotyped behaviors, creativity/imagination, social interaction, and communication. The ADOS inadequately assesses teenagers' restricted and repetitive behaviors when conducted within a one-hour timeframe. The ADOS algorithm evaluates the aggregate scores of the "Communication" and "Social Interaction" dimensions [22]."

In Sweden, the Ritvo Autism and Asperger Diagnostic Scale-Revised (RAADS-R), an 80-item instrument based on DSM-IV-TR and ICD-10 criteria, is used for diagnosis [23]. Social interaction, language, restricted interests, and sensory-motor symptoms are the four domains that make up the RAADS-R self-assessment. According to a Swedish validation study, the lack of adequate internal consistency led to the elimination of the language sub-scale. Individuals on the autistic spectrum are assessed with the RAADS-R, which measures their cognitive, sensory-motor, and perceptual abilities. A clinical diagnosis of autism spectrum disorder (ASD) is indicated by a score of 65 or more on an individual item rating scale from 0 to 3. The American Psychiatric Association (1994) states that the Adult ADHD Self-Report Scale (ASRS) has eighteen questions overall and is divided into two subscales that measure inattention and hyperactivity/impulsivity, respectively. Results between 17 and 23 on each subscale indicate a probable diagnosis of ADHD, while scores over 23 suggest a substantial likelihood of ADHD. The youngsters themselves completed the Wender Utah Rating Scale (WURS) to assess their symptoms of Attention Deficit/Hyperactivity Disorder (ADHD) [24].

2.2.2 Neural Evaluation

The Neurological Assessment Scale (NES), a 26-item instrument employed in clinical settings to evaluate neurological soft signs, was used to conduct a neurological evaluation [25]. Indicators of sensory integration include graphesthesia, right-left confusion, and audio-visual integration. Motor coordination signs include tandem walking, fast alternating actions, and the finger-to-nose evaluation. Motor sequencing indicators include fist-ring, fist-edge-palm, rhythm-tapping-producing movements, and the Ozeretski test. Supplementary neurological signs include the Romberg sign, tremors, mirror movements, silkiness, convergence, basic reflexes, and short-term memory impairments. A score of 0 means the absence of anomalies; 1 defines moderate impairment, and 2 reflects severe impairment for each category.

2.3 Process for PET-scans

Patients underwent mental evaluations, and PET scans measuring regional cerebral blood flow (rCBF) with [1-11C] butanol were conducted. According toward [26], Butanol tagged with 11C or 15O is a dependable blood flow tracer, according to human research. Our in-house cyclotron and radiochemistry equipment allowed us to attach the PET camera swiftly after production. Researchers used a 5-millimeter spatial resolution SBS Biograph 64 Positron Emission Tomography/Computed Tomography (PET/CT) scanner for the investigation. The setup includes a PET scanner with 32,448 LSO crystals arranged in 52 rings, a high-speed ultra 32-detector-row CT machine with 672 detectors per row, and an axial field of view of 21.6 cm. A brain CT scan was performed before making any adjustments to the attenuation or photon scatter. We started the PET scan at the same time as the 300 MBq bolus of [1-11C] butanol, and we recorded the data in list mode for 5 minutes. Reconstructing the dynamic data allowed for the generation of transverse images for rCBF evaluations. The ideal duration for collecting raw data for picture reconstruction and analysis was forty-and-one hundred seconds post-injection. Following the conclusion of this phase, the absorption of [1-11C] butanol reached its zenith and then diminished [27].

2.3.1 Preprocessing of Images

The data was analyzed using Matlab 6.5.1 and the statistical parametric mapping code developed by the Welcome Department of Cognitive Neurology in London, UK. A bilinear interpolation technique was used to normalize the raw data to correspond physically with a PET template aligned with the reference brain at the Montreal Neurological Institute (MNI). The data from the thermalized images was passed through an isotropic Gaussian filter with an aperture of 10 mm FWHM. The pictures were proportionally scaled (0.5) using a grey matter masking threshold of 0.8 for global normalization to increase the signal-to-noise ratio and minimize individual variability in gyral structural features that can impact global cerebral blood flow variations [28].

2.4 Statistical Analysis

We started by using chi-square tests to look at the percentages of the category variables. Because of the small sample size, we used the Fisher exact test to analyze the frequency data. When testing continuous measurement data that did not follow a normal distribution, we used either the t-test or the non-parametric Mann-Whitney U-test. A 0.05 significance level was used.

For each person, thirteen original variables were examined using principal component analysis: verbal and performance IQ, RAADS-, ASRs-, NES-subscales, and total ADOS and GAF scores. Each component will show a different facet of the overall data set variance. The data were normalized using z-score transformation to lessen the high variability in neuropsychiatric scale scores. To do this, we divided each raw score by the population standard deviation after eliminating the averages from the data. An OpenStat Data Set [29] permits further exploration of the obtained z-scores for the thirteen factors that were chosen.

The thirteen native neuropsychological measures were normalized and subjected to principal component analysis, which used varimax orthogonal rotation to calculate the values corresponding to all the variance percentages. Our final decision was to establish a minimum of 1.0 root rotation and a maximum of 25 iterations—parts with eigenvalues greater than one were initially removed. Each variable was considered to have a good representation of its component if its absolute factor loading was more than 0.5. This value is often utilized despite being utterly random since it captures a large percentage of the component's volatility. Measures of sample adequacy (MSA) that surpass 0.7, according to Kaiser-Meyer-Olkin, suggest substantial findings.

Both neurotypical controls (NC) and people with Autism Spectrum Disorder (ASD) have had their regional cerebral blood flow (rCBF) and the characteristics above studied in separate studies. Only single-subject variables were considered in the SMP2 design paradigm. Gender and age were both represented in the research. Due to the limited number of participants in this exploratory investigation, $p = 0.05$ was used as the statistical threshold for voxel height, 0.05 for cluster level, and 0.001 for voxel level. Clusters with more than 125 neighboring voxels, each measuring 11 mm × 11 mm, or roughly twice the intrinsic spatial resolution, were shown to be crucial for assessing the partial volume impact caused by the PET camera's spatial resolution. The conversion of statistical parametric maps (SPM{t}) into SPM{z} units, which represent the standard normal distribution, was necessary. The SPM template's coordinates are out of sync with the Talairach brain, so they must be tweaked. The subroutine created by Matthew Brett may be seen at http://www.mrc-cbu.cam.ac.uk/. Imaging allowed us to do this. When the data was imported into the Talairach client, the Brodmann areas (BAs) were defined to be within 1 mm of the updated Talairach coordinates of the SPM output isocenters.

3. Results

When comparing the ASD and NC groups on these demographic factors, there was no significant difference in age, intellect, smoking habits, handedness, or sex distribution [30].

The three components, "Autistic/ADHD traits" (F1), "Sensory-motor integration" (F2), and "Intelligent/Motor sequencing" (F3), were determined by principal component analysis of symptom ratings. Age and educational level were determined to have no impact on these components. In Table 2, you can see the loading for all three elements.

Table 2. The factor loadings for the neuropsychiatric scale measures

Variables	***Component***			***h*2**
	F*1. *Autistic/ADHD traits	***F*2. *Sensory− motor integration***	***F*3. *Intelligence/ Motor sequencing***	
Hyperactivity/impulsivity subscale in ASRS	**0.840**	−0.255	0.335	0.87
The RAADS-R subscale for limited interests	**0.825**	0.375	0.038	0.92
Inattention subscale in ASRS	**0.805**	0.037	0.066	0.64
ADOS communication and Social interaction	**0.797**	0.342	0.251	0.82
The RAADS-R subscale for sensory motor symptoms	**0.765**	0.317	0.513	0.94
Global assessment of function, total	**−0.756**	−0.468	−0.276	0.86
The RAADS-R subscale for sensory motor symptoms	**0.752**	0.453	0.273	0.83
“Hard” signs NES	**0.564**	0.384	0.412	0.64
A subscale of the NES measuring motor coordination signs	0.033	**0.934**	0.057	0.86
Level of Sensory Integration in the NES	0.315	**0.619**	0.187	0.50
Verbal IQ	−0.245	0.031	**−0.865**	0.81
Performance IQ	−0.238	−0.207	**−0.891**	0.88
The subscale for motor sequencing signs in the NES	0.297	0.518	**0.728**	0.87
Explained cumulatively	38.5	19.8	22.8	

Bold are the factor loadings that are the highest. The variance explained by the component solutions of each item is represented by h2, which stands for commonality. The ADOS, the Neurological Evaluation Scale (NES), the Adult ADHD Self-Report Scale (ASRS), and the Ritvo Autism and Asperger Diagnostic Scale-Revised make up this set. The acronym IQ is the source of "Intelligence Quotient."

In both groups, all three measurements showed strong positive and negative relationships with rCBF (see Table 3).

Table 3. Areas displaying either positive or negative correlations between the three parameter z-scores and cerebral blood flow (CBF)

Structures		***Brodmann area***		***F*1. *Autistic/ADHD traits***				***F*2. *Sensory−motor integration***				***F*3. *Intelligence/ Motor sequencing***		
***ASD*, *n* = 13**		***Control*, *n* = 10**		***ASD*, *n* = 13,**		***Control*, *n* = 10**		***ASD*, *n* = 13**		***Control*, *n* = 10**				
Pos	***Neg***	***Pos***	***Neg***	***Pos***	***Neg***	***Pos***	***Neg***	***Pos***	***Neg***	***Pos***	***Neg***			
Ventral lateral nucleus		Thalamus			R L				L				L	
Lentiform nucleus		Putamen			R				R L	L				
		Caudate		R L										
Sensory-motor cortex		4		R										
Precuneus		6						R						
Insula		12										R	L	
Cuneus		12				R L		L						
Cuneus		17				R		R L			R			
Fusiform gyrus		18						R L			R L			R
Superior temporal gyrus		20								L		R		
Superior temporal gyrus		21					R			L		R		
Superior temporal gyrus		39				L								
Temporo-parietal junction		39/41		R		R								
Parahippocampal gyrus		Hippocampus			R									
The cingulate posterior		24		L										
Hipothalamid gyrus		34				L								
Hipothalamid gyrus		37				L								
Hipothalamid gyrus		38				L		R						
Uncus		21											R	
Inferior frontal gyrus		46										R		
Superior frontal gyrus		11, 12			R									
Anterior cingulate		33			R									
Inferior frontal gyrus		32							R L					
Inferior frontal gyrus		46							R					

The red dots signify persons with Autism Spectrum Disorder (ASD), whereas the green dots denote healthy controls; the association between rCBF and "autistic/ADHD traits" exists between the two groups. Areas where the "autistic/ADHD traits" component in NC (green) and ASD (red) have a positive connection with rCBF. The first row illustrates the brain's medial aspect; the subsequent row presents its anterior and posterior regions; the third row exhibits its right and left hemispheres in juxtaposition; and the concluding row represents the anterior and posterior views of its inferior component and its superior aspect [31].

The research found a favorable correlation between regional cerebral blood flow (rCBF) and "sensory-motor integration" in both neurotypical persons (green) and patients with ASD (red). Green areas indicate NC, whereas red parts demonstrate a positive link between rCBF and "sensory-motor integration" in patients with ASD. Row one presents the front and posterior views of the two hemispheres; row two illustrates their lateral and oblique perspectives; row three showcases their lateral and oblique components; and row four reiterates their lateral and oblique features [32].

In a study conducted in North Carolina, researchers found that the "Autistic/ADHD traits" score was positively correlated with cerebral blood flow in the occipital and temporal cortices. In autism spectrum disorder (ASD), there are bilateral connections in the motor cortex, right inferior parietal lobule, posterior cingulate, and caudate. On the other hand, the ASD group showed negative associations in the right putamen and prefrontal cortex [33].

Interactions between NC and ASD in the "Sensory-motor integration" component were inconsistent, and the occipital association cortex had both positive and negative associations. This held in the putamen as well, where CBF correlated positively with NC and negatively with ASD [34].

Intelligence/Motor sequencing" found an association with cerebral blood flow in the ASD group, namely in the right temporal cortex, left insula, and right uncus. The correlation was negative in the other groups. Across all three metrics, the left thalamus of individuals with ASD showed a negative association [35].

4. Discussion

According to this study, "Autistic/ADHD traits" include characteristics of autism as well as symptoms of ADHD. Resting regional cerebral blood flow in intersecting brain regions may be associated with autistic traits and ADHD symptoms, according to our findings. Regional cerebral blood flow was associated with neurological soft indicators and intelligence/motor sequencing, independent of ASD or ADHD [36].

4.1 Relationship between rCBF and "Autistic/ADHD Traits"

There are neurobiological connections between ASD and ADHD symptoms in some regions of the brain, as shown by an auditory association between cerebral blood flow (CBF) and the characteristic "Autistic/ADHD traits" in autistic persons. Research has linked ASD and ADHD to several areas of the brain, including the sensory-motor cortex, caudate, middle and superior temporal gyrus, and the temporoparietal junction [37].

The intricate tasks associated with the temporoparietal junction (BA 39/40) need knowledge of biological motion, gaze direction in space, and the integration of auditory and visual information to facilitate substantial emotional and social reactions. The ability to interpret metaphors and the intentions of others, as well as moral judgment, are related to this region, which is relevant to ASD. Autism spectrum disorder (ASD) and attention deficit hyperactivity disorder (ADHD) are associated with a ventral attention system that is right-lateralized and involves the tempo-parietal junction. A decreased capacity to concentrate on critical social signals and an inclination to become distracted are associated with this system. Participants with autism had much higher levels of extraordinary activations in this region during a verbal memory test compared to healthy controls, according to PET research [38].

We discovered strong correlations between the "Autistic/ADHD traits" component and cerebral blood flow in the postcentral gyrus (BA 3), the area of the brain responsible for processing somatic sensations, suggesting that positive correlations in this domain could be linked to distorted somatic sensory perceptions seen during PET scans [39].

The caudate has been associated with ASD due to its role in executive dysfunction and ritualistic behavior [40]. Directional projections from the associative cortices to the caudate nucleus inside the striatum are standard. The caudate positively correlates with cerebral blood flow (CBF) and "Autistic/ADHD traits" because of its strong functional and physical links to the parietal and temporal lobes, crucial to several brain circuits. Due to the intricate network architecture that underpins the human brain's architecture and functions, information may be more readily segregated and incorporated. When it comes to link networks, people on the autism spectrum are likely to have short-range augmentation and long-range impairment. An overflow of information processing, brought on by this anatomical-functional loop, may lead to a localized surge in blood flow and metabolism under certain conditions. The distance between the rostral brain area and the temporoparietal junction/posterior cingulate cortex likely explains the negative link between "Autistic/ADHD traits" and the prefrontal cortex.

4.2 rCBF and "Sensory-Motor Integration"

This study demonstrated that neurological soft indicators play a pivotal role in the ASD phenotype, according to findings from NES sub-scales evaluating motor coordination and sensory integration. Table 3 indicates that in NC, there is a negative link, whereas in the cuneus and fusiform gyrus, there are positive associations with CBF in ASD patients [41].

One of the diagnostic criteria for autism spectrum disorder, according to the 1994 Diagnostic Criteria for Autism Spectrum Disorder by the American Psychiatric Association, is inadequate use of facial expressions and eye contact. Issues in recognizing faces are a component of low social skills. It was shown that the dorsolateral occipital cortex was the region most often activated when subjects were asked to match faces. Object perception, face processing, and recognition were all linked to the fusiform gyrus in a neurotypical group, on the other hand. Within the fusiform gyrus, where an increase in grey matter volume has been seen in autism spectrum disorders, we found a positive association between cerebral blood flow and the factor "Sensory-motor integration" in patients. One possible explanation for the enhanced visual cortex local neuronal activity is that the favorable connection results from the dispersion of information from an autistic perspective, which is vast and diverse [42].

People with autism spectrum disorder (ASD) commonly employ visual techniques to overcome cognitive challenges and display an asocial, visually focused way of thinking, regardless of whether their limitations are verbal or visual. They may struggle with social relationships, exhibit unusual visual perception and spatial ability (which might be a sign of savantism), and pay close attention to detail [43]. Patients with autism spectrum disorder (ASD) may have trouble integrating visual, auditory, proprioceptive, and tactile information cross-modally, as shown by positive relationships between " Cerebral blood flow in the fusiform gyrus and the cuneus and sensory-motor integration. Our findings also suggest that the temporo-occipital regions are involved, which are associated with understanding other people's emotions and motivations.

4.3 In Terms of Intellect and the Sequencing of Motor Events, Serum rCBF

The right insula, middle/superior temporal gyri, and cerebral blood flow were all positively linked with the "Intelligence/Motor sequencing" component in the ASD group. Gaining understanding via visual-spatial and multimodal [44] the insula (BA 13). Additionally, the insula is critical for improving concentration on new sensory inputs and redirecting attention from exterior stimuli to internal ideas. Further, the insula's visual-auditory integration, temporal processing, and phonological processing are all affected by ASD. There may be compensatory mechanisms for impaired integrative functioning, as CBF is positively associated with this area's "Intelligence/Motor sequencing" component. Mental areas like the insula and the sulcus posterior are related to concepts like self-awareness, empathy, and consciousness. The right insular cortex showed increased regional cerebral blood flow (rCBF) in individuals with gender identity disorder (GID). Anxieties are common among those who have ASD. Recent research has linked the increased volume of grey matter in some areas of the insular cortex to sensory-motor processing, which may explain why some people with Gender Identity Disorder (GID) exhibit these symptoms. [45], GID may coexist with Autism Spectrum Disorder (ASD), which opens up new avenues for investigative study.

Associated with BA 21, 22, the superior temporal gyrus is considered the physical basis for sensory integration, language, and metallization. People with ASD and ADHD often struggle with social and conversational skills, as well as noticeable issues with perception, motor skills, and attention, all of which are believed to originate in this region of the brain [46]. Recent studies have shown an association between the "Intelligence/Motor sequencing" component and cerebral blood flow in the superior temporal lobe among individuals with ASD. In contrast, no such association was seen in the control group.

4.4 Thalamus Involvement

This aligns by aberrant neurotransmission in persons with ASD [47]. According to previous studies, thalamic abnormalities and other neurological soft symptoms are more common. The thalamus filters information traveling to the cerebral cortex and aids with motor planning and sensory perception. It is believed that the thalamus plays a part in the maladaptive multisensory integration processing seen in ASD and ADHD. The thalamus may regulate cortical arousal via thalamocortical connections; hyper arousal is another characteristic of ASD.

Consistent with previous studies showing that ASD is associated with difficulties with motor control, hyperactivity, and attention, our results lend credence to a neurological explanation for the disorder. There is evidence that ASD and ADHD share genetic variation and share phenotypic features; thus, this makes sense. In addition, our results are consistent with an underlying component that has been identified before and has a significant impact on both ADHD symptoms and autistic characteristics [48]. Therefore, it is assumed that concurrent ADHD symptoms indicate a more generalized ASD phenotype rather than a distinct comorbid illness, which is crucial for both diagnosis and therapy. Therefore, it is suggested that component analysis of various symptoms, in combination with biological correlates in ASD, is an effective way to investigate the underlying pathophysiological and etiological features.

4.5 Autism Symptom Assessment Tools

This research measured autistic traits using the RAADS-R, a rating scale meant to support ASD diagnostic evaluation. This tool evaluates a broad spectrum of cognitive impairments, repetitious, stereotyped behavior, and sensory-motor abnormalities. Our findings show that ASD is a clinical disorder characterized by many symptomatic features throughout the autistic spectrum. As a result of aberrant brain development, the autism phenotype affects neuronal connection and synchronization [49]. similarities in structure and function may be linked to concurrent problems with linguistic, motorized organization, action, temper, & doze. In our adult ASD group, there are a lot of different mental and psychological diseases. Still, the prevalence of ADHD symptoms, together with problems with motor and sensory integration, might mean that their brains developed differently. Other mental diseases also substantially impact certain regions linked to ASD [50]. Neuroimaging findings in adults with ASD support the idea that a distinct clinical subgroup exists when evaluated sensory-motor impairments co-occur, as opposed to when these abnormalities are self-reported. It is thought that hyperactivity and inattention have neurological roots and interplay within the setting of autism spectrum disorder diagnosis.

4.6 Limitations

The investigations used a peak-level significance criterion of $p < 0.05$ that was not crossed. This liberal method was utilized to decrease type II errors from too rigid criteria, which is standard in neuroimaging research due to the limited sample size norm [51]. The exploratory character of the study raises the possibility of false-negative results in PET studies using higher thresholds, in addition to PET's poor sensitivity in the absence of repeated evaluations. Another concern was that there were no blinded assessors.

5. Conclusions

ASD and ADHD are two different disorders. However, sensory-motor deficits are seen as a unique illness in and of themselves. Their symptoms are based on the exact neurological mechanisms, but other than that, they are different. These particular symptoms indicate dysfunctions in improperly structured neuronal networks in the brain. We conclude that changes in metabolic rate and blood flow in ASD are linked to paspecificeuronal circuits' resting activity.

References

[1] K. I. Al-Sulaiti *et al.*, "Research Methods for Business Students," *Int. Mark. Rev.*, vol. 14, no. 2, p. 656, 2010, doi: 10.4135/9781412986182.

[2] D. Hanahan and R. A. Weinberg, "Hallmarks of cancer: The next generation," *Cell*, vol. 144, no. 5, pp. 646–674, Mar. 2011, doi: 10.1016/j.cell.2011.02.013.

[3] R. M. Baron and D. A. Kenny, "The Moderator-Mediator Variable Distinction in Social Psychological Research. Conceptual, Strategic, and Statistical Considerations," *J. Pers. Soc. Psychol.*, vol. 51, no. 6, pp. 1173–1182, Dec. 1986, doi: 10.1037/0022-3514.51.6.1173.

[4] L. Zoccante, M. L. Ciceri, L. A. Gozzi, G. Di Gennaro, and N. Zerman, "The 'connectivome theory': a new model to understand autism Spectrum disorders," *Front. Psychiatry*, vol. 12, p. 794516, 2022.

[5] H.-Y. Lin, H.-C. Ni, W.-Y. I. Tseng, and S. S.-F. Gau, "Characterizing intrinsic functional connectivity in relation to impaired self-regulation in intellectually able male youth with autism spectrum disorder," *Autism*, vol. 24, no. 5, pp. 1201–1216, 2020.

[6] M. Chakrabarty, "Brain correlates of cognitive-behavioural manifestations in Autism Spectrum Disorder." IIIT-Delhi, 2022.

[7] A. Paquet, B. Olliac, B. Golse, and L. Vaivre-Douret, "Current knowledge on motor disorders in children with autism spectrum disorder (ASD)," *Child Neuropsychol.*, vol. 22, no. 7, pp. 763–794, 2016.

[8] J. K. Kern, D. A. Geier, L. K. Sykes, M. R. Geier, and R. C. Deth, "Are ASD and ADHD a continuum? A comparison of pathophysiological similarities between the disorders," *J. Atten. Disord.*, vol. 19, no. 9, pp. 805–827, 2015.

[9] G. Leisman and R. Melillo, "Functional Disconnectivities in Autistic Spectrum Disorder as a Potent Model for Explaining Disorders of Consciousness And Cognition in the Brain and Nervous System," *Funct. Neurol. Rehabil. Ergon.*, vol. 1, no. 1, p. 101, 2011.

[10] S. Karavallil Achuthan, D. Stavrinos, P. Argueta, C. Vanderburgh, H. B. Holm, and R. K. Kana, "Thalamic functional connectivity and sensorimotor processing in neurodevelopmental disorders," *Front. Neurosci.*, vol. 17, p. 1279909, 2023.

[11] R. Coben, M. Linden, and T. E. Myers, "Neurofeedback for autistic spectrum disorder: a review of the literature," *Appl. Psychophysiol. Biofeedback*, vol. 35, no. 1, pp. 83–105, 2010.

[12] B. Gepner and F. Féron, "Autism: a world changing too fast for a mis-wired brain?," *Neurosci. Biobehav. Rev.*, vol. 33, no. 8, pp. 1227–1242, 2009.

[13] J.-J. Paakki *et al.*, "Alterations in regional homogeneity of resting-state brain activity in autism spectrum disorders," *Brain Res.*, vol. 1321, pp. 169–179, 2010.

[14] A. N. Kaczkurkin *et al.*, "Common and dissociable regional cerebral blood flow differences associate with dimensions of psychopathology across categorical diagnoses," *Mol. Psychiatry*, vol. 23, no. 10, pp. 1981–1989, 2018.

[15] Y. Yang *et al.*, "Repetitive transcranial magnetic stimulation modulates long-range functional connectivity in autism spectrum disorder," *J. Psychiatr. Res.*, vol. 160, pp. 187–194, 2023.

[16] N. D. Woodward, M. Giraldo-Chica, B. Rogers, and C. J. Cascio, "Thalamocortical dysconnectivity in autism spectrum disorder: An analysis of the Autism Brain Imaging Data Exchange," *Biol. Psychiatry Cogn. Neurosci. Neuroimaging*, vol. 2, no. 1, pp. 76–84, 2017.

[17] Y. Wang *et al.*, "HD-tDCS effects on social impairment in autism spectrum disorder with sensory processing abnormalities: a randomized controlled trial," *Sci. Rep.*, vol. 15, no. 1, p. 9772, 2025.

[18] J. Deng, T. Lei, and X. Du, "Effects of sensory integration training on balance function and executive function in children with autism spectrum disorder: evidence from Footscan and fNIRS," *Front. Psychol.*, vol. 14, p. 1269462, 2023.

[19] R. Melillo *et al.*, "Retained primitive reflexes and potential for intervention in autistic spectrum disorders," *Front. Neurol.*, vol. 13, p. 922322, 2022.

[20] M. W. Mosconi, Z. Wang, L. M. Schmitt, P. Tsai, and J. A. Sweeney, "The role of cerebellar circuitry alterations in the pathophysiology of autism spectrum disorders," *Front. Neurosci.*, vol. 9, p. 156522, 2015.

[21] J. Zhang *et al.*, "Neural, electrophysiological and anatomical basis of brain-network variability and its characteristic changes in mental disorders," *Brain*, vol. 139, no. 8, pp. 2307–2321, 2016.

[22] S. Salloum-Asfar, A. K. Elsayed, and S. A. Abdulla, "Potential approaches and recent advances in biomarker discovery in autism spectrum disorders," *Neural Eng. Tech. autism Spectr. Disord.*, pp. 121–145, 2023.

[23] Y. Wang *et al.*, "High definition transcranial direct current stimulation of the Cz improves social dysfunction in children with autism spectrum disorder: a randomized, sham, controlled study," *Autism Res.*, vol. 16, no. 10, pp. 2035–2048, 2023.

[24] B. Sütçübaşı *et al.*, "Differentiating Functional Connectivity Patterns in ADHD and Autism Among the Young People: A Machine Learning Solution," *J. Atten. Disord.*, p. 10870547251315230, 2025.

[25] D. R. A. Coelho, C. Renet, S. López-Rodríguez, P. Cassano, and W. F. Vieira, "Transcranial photobiomodulation for neurodevelopmental disorders: A narrative review," *Photochem. Photobiol. Sci.*, vol. 23, no. 8, pp. 1609–1623, 2024.

[26] P. M. Kidd, "Autism, an extreme challenge to integrative medicine. Part 1: The knowledge base," *Altern. Med. Rev.*, vol. 7, no. 4, pp. 292–316, 2002.

[27] C. Gupta *et al.*, "Bringing machine learning to research on intellectual and developmental disabilities: taking inspiration from neurological diseases," *J. Neurodev. Disord.*, vol. 14, no. 1, p. 28, 2022.

[28] R. Rose'Meyer, "A review of the serotonin transporter and prenatal cortisol in the development of autism spectrum disorders," *Mol. Autism*, vol. 4, pp. 1–16, 2013.

[29] Y. Lu, L. Zhang, X. Wu, F. Fei, and H. Han, "Systematic bibliometric and visualized analysis of research hotspots and trends on autism spectrum disorder neuroimaging," *Dis. Markers*, vol. 2022, no. 1, p. 3372217, 2022.

[30] S. Xu *et al.*, "Abnormal degree centrality in children with low-function Autism Spectrum disorders: a sleeping-state functional magnetic resonance imaging study," *Neuropsychiatr. Dis. Treat.*, vol. 18, p. 1363, 2022.

[31] E. B. Torres and K. Denisova, "Motor noise is rich signal in autism research and pharmacological treatments," *Sci. Rep.*, vol. 6, no. 1, p. 37422, 2016.

[32] R. Melillo, "Persistent primitive reflexes and childhood neurobehavioral disorders," *Neuroplast. Learn. Rehabil.*, p. 65, 2016.

[33] C.-R. Hagemann, "A sensory-motor integration programme for boys with autism spectrum disorder: two case studies." Stellenbosch: Stellenbosch University, 2014.

[34] F. Marciano *et al.*, "Artificial intelligence: The 'Trait D'Union' in different analysis approaches of autism spectrum disorder

studies," *Curr. Med. Chem.*, vol. 28, no. 32, pp. 6591–6618, 2021.
[35] R. L. Shafer, Z. Wang, J. Bartolotti, and M. W. Mosconi, "Visual and somatosensory feedback mechanisms of precision manual motor control in autism spectrum disorder," *J. Neurodev. Disord.*, vol. 13, pp. 1–17, 2021.
[36] T. Armstrong, *Neurodiversity: Discovering the extraordinary gifts of autism, ADHD, dyslexia, and other brain differences*. ReadHowYouWant. com, 2010.
[37] L. Zwaigenbaum and M. Penner, "Autism spectrum disorder: advances in diagnosis and evaluation," *Bmj*, vol. 361, 2018.
[38] F. Fulceri, "Early motor signature in autism spectrum disorder," 2019.
[39] B. Yakubov *et al.*, "Cross-frequency coupling in psychiatric disorders: a systematic review," *Neurosci. Biobehav. Rev.*, vol. 138, p. 104690, 2022.
[40] I. Manouilenko *et al.*, "Autistic traits, ADHD symptoms, neurological soft signs and regional cerebral blood flow in adults with autism spectrum disorders," *Res. Autism Spectr. Disord.*, vol. 7, no. 5, pp. 566–578, 2013.
[41] D. Tantam, *Autism spectrum disorders through the life span*. Jessica Kingsley Publishers, 2012.
[42] P. M. Kidd, "Autism, an extreme challenge to integrative medicine. Part II: Medical management," *Altern. Med. Rev.*, vol. 7, no. 6, pp. 472–499, 2002.
[43] X. Ma *et al.*, "Connectome-based prediction of the severity of autism spectrum disorder," *Psychoradiology*, vol. 3, p. kkad027, 2023.
[44] J.-J. Paakki, "BOLD fMRI detectable alterations of brain activity in children and adolescents on the autism spectrum," 2023.
[45] S. Icer, S. G. Benli, K. Gumus, E. Demirci, S. Ozmen, and S. Doganay, "Can functional connectivity at resting brain in ADHD indicate the impairments in sensory-motor functions and face/emotion recognition?," *J. Med. Biol. Eng.*, vol. 38, pp. 138–149, 2018.
[46] S. D. Tomchek, "Characterizing sensory processing in autism spectrum disorders," 2005.
[47] R. Melillo and G. Leisman, *Neurobehavioral disorders of childhood: An evolutionary perspective*. Springer Science & Business Media, 2010.
[48] Y. Yang, P. Song, and Y. Wang, "Assessing the impact of repetitive transcranial magnetic stimulation on effective connectivity in autism spectrum disorder: An initial exploration using TMS-EEG analysis," *Heliyon*, vol. 10, no. 11, 2024.
[49] J. A. Pineda, A. Juavinett, and M. Datko, "Rationale for neurofeedback training in children with Autism," *Compr. Guid. to Autism*, pp. 439–460, 2014.
[50] V. Arunachalam Chandran, "Investigating the neural correlates of autistic traits using a dimensional approach." University of Reading, 2021.
[51] A. K. Jayanthy and Q. M. U. Din, "Early detection of autism spectrum disorder using behavioral data EEG, MRI and Behavioral Data: A Review," *Assist. Technol. Interv. Healthc.*, pp. 245–267, 2021.