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Sensory processing patterns among children with autism spectrum disorder (ASD) and attention deficit hyperactivity disorder (ADHD) using short sensory profile and evoked potentials: a case–control study

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Abstract

Background Both autism spectrum disorder (ASD) and attention-deficit hyperactivity disorder (ADHD) are early neurodevelopmental disorders that present notable diagnostic problems and share clinical features. The current research intends to clarify the sensory profile, visual-evoked potential (VEP), and auditory-evoked potential of children diagnosed with autism spectrum disorder (ASD), ADHD, and typically developing children (TD). We have observed sensory processing problems in 42–88% of children diagnosed with autism and approximately 50% of children diagnosed with ADHD.

Results The parents of 37 children diagnosed with ASD, 41 children diagnosed with ADHD, and 43 children who were typically developing completed the short sensory profile (SSP) along with standardized questionnaires used to assess the symptoms and autistic behaviors. We assessed intellectual functioning and evoked potential in all the groups. There were more sensory problems in the ASD and ADHD groups than in the control group ($P < 0.001$); however, autism and ADHD differed in all subscales except unresponsiveness, auditory filtering, and visual/auditory subscales. Also, the ASD group and ADHD group showed a more significant delay in visual-evoked potential VEP than the control group (mean and SD of right eye p100 latency 150.85 ± 48.70 in ASD vs 119.28 ± 18.06 in ADHD vs 103.42 ± 5.19 in typically developing group, left p100 latency 141.09 ± 32.55 in ASD vs 116.51 ± 10.1 in ADHD vs 103.0 ± 5.91 typically developing group). Additionally, the ASD group significantly deviated from norms in the absolute latency of waves I, III, and V, as well as the inter-wave intervals of I–III and III–V in the auditory-evoked potential. Furthermore, there was a statistically significant distinction between the ADHD and the TD groups in terms of left wave III and V latency and left interpeak latency between I–III and III–V.

Conclusion Children diagnosed with ASD and ADHD have a greater likelihood than typically developing children to experience sensory processing abnormalities; as a result, we recommend basic assessment, follow-up, and designing the most appropriate intervention.

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Keywords Autism, Attention deficit hyperactivity disorder, Short sensory profile, Visual-evoked potential, Auditory-evoked potential

Introduction

Neurodevelopmental disorders including attention deficit hyperactivity disorder (ADHD) and autism spectrum disorder (ASD) are often linked to atypical reactions to sensory stimuli [1]. The varied presentations of ASD distinguish it as a neurodevelopmental disorder. ASD commonly manifests as a combination of the following symptoms: typically starting in early infancy, these conditions can include impaired social communication, repetitive behaviors, sensory abnormalities, and/or restricted interests. A recent cohort research in Sweden found that the prevalence of ASD and ADHD was 1.1% and 7.6%, respectively [2].

Sensory integration refers to the act of combining sensory information from different parts of the body's organs into one organization, which is then processed by the brain to complete the perception of the inside and outside of the body and provide feedback [3].

Sensory processing disorder (SPD) is defined by [4] as a dysfunction that impairs the appropriate reception, modulation, integration, discrimination, or organization of sensory stimuli, as well as behavioral responses to sensory input.

Dunn (1991) stated that an individual's reaction to a sensory stimulus can differ according to their neurological threshold. When these brain functions, known as sensory processing (SP), are disrupted, two types of atypical SP can result [5]. A high neurological threshold is linked to hyporeactivity to sensory stimuli. In contrast, low neurological thresholds are linked to hyper-reactivity, which can impact all sense modalities (tactile, auditory, taste, vestibular, olfactory, and proprioceptive). In the general population, 12% of children have atypical SP, which necessitates the development of methods to modify their behavior in everyday situations [6].

People with SPD have trouble responding to, organizing, and processing sensory data, which makes it difficult for them to engage in tasks and routines that are necessary for daily functioning [7]. Moreover, most individuals with ASD react abnormally to sensory stimuli [8]. This includes depressive, anxious, hyperactive, and aggressive states [9, 10]. Studies reveal that children with typical development receive sensory information differently than those with ASD and ADHD [11–14]. ASD is frequently associated with differences in sensory processing [15]. They were just listed among DSM-5 for the illness [16].

Both the proper amount of synaptic contact and the appropriate pace of neural transduction are necessary

for normal brain function. One of the main factors influencing higher electrical conductivity in nerve fibers is the existence of the myelin coating. The plasma membrane of glial cells produces myelin, a fatty substance essential for rapid neural communication. Myelination, a crucial step in brain development, involves the creation of the myelin coating around axons. It begins early in development in the motor and sensory pathways, which include the visual pathway [17].

Visual-evoked potential (VEP) is a technique that records the electrophysiological signals of the brain across the occipital lobe in reaction to simple visual input. People in general use VEP to determine optic nerve lesions and evaluate visual functions [18]. Numerous research investigations have demonstrated anomalies in VEP in a variety of mental and neurological illnesses, such as schizophrenia, migraine headaches, and Alzheimer's disease [19].

Children who experience developmental delays may also exhibit VEP anomalies. Children with developmental delays frequently have delayed nerve conduction, reflected in the VEP waveforms' lengthening. Visual system abnormalities, like poor eye control and light sensitivity, are commonly seen in children diagnosed with autism. These unusual findings might be the consequence of anomalies in the brain networks responsible for social cognition or faulty sensory processing. In a recent study using steady-state VEP, patients with high-functioning autism showed hyperresponsivity to visual stimuli [20].

The auditory brainstem response (ABR) is an auditory-evoked potential represented by a waveform with five waves: the auditory nerve is where wave I begins, while the upper brainstem is the source of wave V. Latest studies have shown infants with ASD, later on, had a longer wave V latency. Infants and kids with ASD consistently had prolonged ABR, demonstrating that it may function as a biomarker for ASD in young children [21, 22]. Studies have shown that young infants with probable ASD already exhibit signs of a neurological brainstem dysfunction. The claim that an auditory processing deficiency may be the fundamental cause of this condition is supported by the results of the ABR [23].

Few researchers have used the results of VEP and ABR testing as brain maturation markers to compare and contrast the degree of sensory processing disparities and overlaps between children diagnosed with ASD and ADHD. Therefore, this study aimed to compare

children with autism spectrum disorder (ASD), attention-deficit hyperactivity disorder (ADHD), and healthy children using the short sensory profile, visual-evoked potential, and auditory-evoked potential.

Subjects and methods

Thirty-seven children with autistic disorder and 41 children with attention deficit hyperactive disorder were included in this study, and aged 6–16 years, who fulfilled the criteria of the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-5) and were recruited from the outpatient psychiatry clinic at Mansoura University Hospital were included in this study. Children with other psychiatric diseases and children with visual and auditory defects were excluded. Forty-three age- and sex-matched controls were included in the study. They were chosen from outpatient clinic attendees other than a psychiatry clinic at Mansoura University Children's Hospital. Before the procedure, parents or other carers gave their informed consent, and the research subjects underwent the following:

Clinical evaluation through taking history, comprising the child's sociodemographic details, details on the perinatal period, developmental history, family background, and history of autism disorder, as well as information on the illness's origin, course, and symptoms, as well as a thorough medical examination.

- *Psychometric assessment tools*: We used a progressive matrices intelligence exam which was used to evaluate intellectual capacity, and CARS was used to classify the degree of autism symptoms. The Vanderbilt ADHD Diagnostic Parent Rating Scale was used to classify the ADHD subtype. A short sensory profile was used to evaluate SPD.
- *Semistructured Clinical Interview for Children and Adolescents (SCICA/6–18)* was used.
- *Neurophysiological assessment tools*: Visual- and auditory-evoked potential were assessed.

Tools

The Semistructured Clinical Interview for Children and Adolescents (SCICA)

It is a clinical interview for children ages 6–18. The SCICA Observation Form has 120 items to rate observations of children's behavior, affect, and interaction style. Examples include fighting; avoiding eye contact; defiant, talking back, or sarcastic; disconnected or tangential communication; does not sit still, restless, or hyperactive; limited discourse; sudden changes in mood or feelings; and miserable, sad, or melancholy.

The SCICA Profile has six additional scales for scoring problem items consistent with DSM-5 diagnoses: affective problems, anxiety problems, somatic problems, attention deficit/hyperactivity problems, oppositional defiant problems, and conduct issues [24, 25].

The reliability and validity of the SCICA have been established for an Arab sample [26, 27].

Short sensory profile (SSP)

The short sensory profile [28] is a caregiver report scale applied in clinical and research settings to evaluate sensory problems in children who have autism spectrum disorder and those who do not. The shorter SSP expands the sensory profile (SP) [5].

Seven subscales divide the 38 items in the SSP: there are 6 items in the low-energy/weak subscale, 7 items in the under-responsive/seeks sensation subscale, 7 items in tactile sensitivity, 4 items in the taste/smell sensitivity subscale, 3 items in the movement sensitivity subscale, 6 items in the auditory filtering (AFL), and 5 items in the visual/auditory sensitivity. We used the Arabic version [29].

Childhood Autism Rating Scale (CARS)

The 15-item CARS is an observation-based rating scale that assesses social, emotional, cognitive, adaptive, and communication abilities among other functions. Its purpose is to accurately pinpoint, quantify, and differentiate ASD symptoms from those of other developmental disorders. We used a 4-point rating system (1, 1.5, 2..., 4) for each of the 15 items. Whereas a score of 4 denotes "severe symptoms for that age, while a score of 1 denotes "within the normal range for that age," with a minimum CARS score of 15. The cutoff for diagnosing ASD was 30, and the maximum CARS score was 60 [30] provided the translation into Arabic.

Vanderbilt ADHD diagnostic parent rating scale

To evaluate ADHD, the parent-reported VADPRS has strong concurrent validity, factor structure, and internal consistency. The VADPRS has 18 ADHD symptoms, each of which is graded on a 4-point scale (0 = never, 1 = occasionally, 2 = often, and 3 = very often) to indicate how frequently it occurs, and Arabic translation of it is available [31].

Scores are presented for the three subtypes of ADHD:

1. Predominately inattentive subtype: A child meets the diagnostic criteria if they have six or more "often" or "very often" on items 1 to 9, plus a performance problem (scores of 1 or 2) on questions 48 to 55.
2. Predominately hyperactive/impulsive subtype: A child meets diagnostic criteria if they have six or

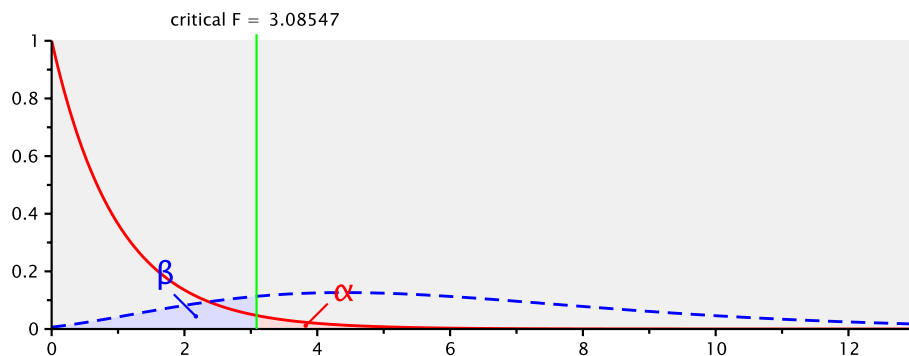


Fig. 1 Sample size calculation by G power

more “often” or “very often” on items 10 through 18, plus a performance.

3. Combined subtype: A child meets the diagnostic criteria if they meet the above criteria for both inattentive and hyperactive/impulsive subtypes.

- Inattentive subtype = items 1 to 9
- Hyperactive/impulsive subtype = items 10 to 18

Raven progressive matrices

We used the “Raven’s Colored Progressive Matrices 1998 edition,” which has 36 questions divided into three segments A, Ab, and B, to estimate each child’s IQ. The test is nonverbal and has one missing component. The questions follow a geometric structure. We converted the obtained data to percentiles and evaluated the final result using Raven’s *Colored Progressive Matrices* handbook [32].

Visual-evoked potentials (VEP)

The experiment was carried out in a room with moderate lighting, with the video monitor positioned at a distance of 1 m (range = 75–150 cm). The monitor was precisely calibrated from the nose to the screen; high contrast (> 80%) black and white checks were shown on the screen, and when visual stimulation occurred, they abruptly reversed with a reversal rate of < 4 reversals/s (blacks turned into whites, and whites turned into blacks) [33].

Auditory-evoked potential

An earphone or headphone is an example of an acoustic transducer, which transmits a brief click or tone pip that generates the evoked potential. Surface electrodes, usually positioned at the scalp’s vertex and the lobes of the ears, measured the elicited waveform response, similar to electroencephalography. The peaks of the waveform have

labels I–VII. These waveforms often appear 10 ms after a click stimulus that is delivered at loud levels (70–90 dB) over the average level of hearing [34].

Sample size calculation

Sample size calculation was based on sensory profile between cases with ADHD, ASD, and control group based on the domain that yields the highest sample size. Using G*Power program version 3.1.9.7 to calculate sample size based on effect size of 0.31, using 2-tailed test, α error = 0.05, and power = 80.0%, the total calculated sample size will be 35 in each group at least (Figs. 1 and 2).

Statistical analysis and data interpretation

SPSS software, version 25 (SPSS Inc., PASW Statistics for Windows version 25), performed the data analysis, Chicago: SPSS, Inc. We used percentages and statistics to explain the qualitative data. After using the Kolmogorov–Smirnov test to verify normality, the mean \pm standard deviation was utilized to characterize quantitative data for normally distributed data and the median (minimum and maximum) (interquartile range) for non-normally distributed data. The acquired results were deemed significant at the ≤ 0.05 level.

Results

We classified our total sample of 121 children into three groups. Thirty-seven children had ASD, 41 children had ADHD, and 43 children normally developed. According to Table 1, no statistical distinctions among the studied groups regarding age, sex, or residence have been found. The mean and SD of the ASD group were 8.46 ± 2.69 , the mean and SD of the ADHD group were 9.34 ± 2.15 , and the mean and age group of the normally developed children were 8.63 ± 2.38 .

Table 2 reveals a notable variation among the studied groups related to intellectual function. In the ASD group, 13.5% were intellectually superior to the 26.8% in the

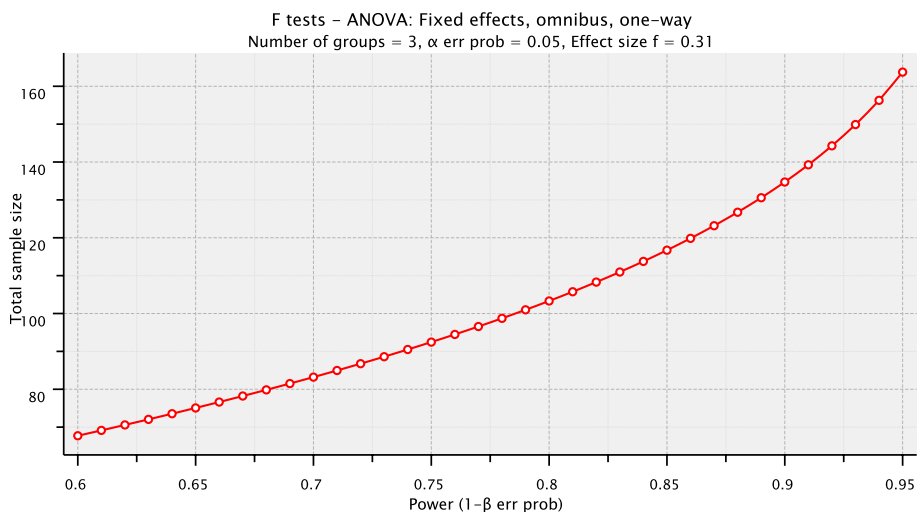


Fig. 2 Sample size calculation by G power

group of ADHD. A total of 16.3% in the normal group and 29.7% in the ASD group were above the average intellectual capacity; 14.6% in the ADHD group in contrast to 55.8% in the normal group; 24.3% in the ASD group were intellectually average, in contrast to 51.2% in the ADHD group and 20.9% in the normal group; and 32.4% were clearly below the average, compared to 7.3% in the group of ADHD and 7% in the normal group.

Table 3 displays statistically notable differences between the groups regarding the Childhood Autism Rating Scale and Vanderbilt. For example, the mean and standard deviation of the ASD group were 37.22 ± 3.89 , while the mean and standard deviation of the Vanderbilt ADHD Scale in ADHD were 34.05 ± 3.85 .

The findings, shown in Table 4, revealed a notable different sensory processing pattern between the healthy children and both the diagnosed groups in all measures. This meant that the healthy participants had less severe sensory processing problems. We observed no differences between the two diagnosed groups regarding under responsive/sensory seeking, auditory filtering, and visual/auditory subscales. In the ASD group, those with a “definite difference” in sensory processing represented 73% of the cases, 27% had a “probable difference,” and 0% had a “typical performance.” In the ADHD group, 80.5% of respondents were classified as having a possible sensory deficiency or a definite sensory processing deficit, and 19.5% ($n=8$) had a typical performance.

Table 5 regarding p100 latency in VEP showed that the group of autism had a more notable delay regarding VEP than the group of ADHD and the normal group (Rt eye p100 latency in ASD was 150.85 ± 48.70 vs 119.28 ± 18.06 in ADHD versus 103.42 ± 5.19 in

normal, left p100 latency 141.09 ± 32.55 vs 116.51 ± 10.1 vs 103.0 ± 5.9). Regarding ABR, we also found considerable variations between autism and the healthy group regarding the absolute latency of waves I, III, and V, as well as the inter-wave intervals of I–III and III–V. The TD group and the ADHD group differed statistically significantly. They were regarding left waves III and V latency and left interpeak latency between I–III and III–V.

In Table 6, a negative correlation between the SSP total and all subscale scores and the degree of autistic symptoms measured by CARS have been observed; in other words, the more severely autistic the child was, the more sensory deficits they experienced.

Table 7 revealed no statistically considerable correlation between the degree of autism spectrum disorder and p100 latency.

Table 8 showed that the subtype of ADHD had no relation to the type of sensory deficit.

Table 9 showed no notable link between the type of ADHD and the p100 latency in VEP, the absolute latencies, or the interpeak latencies of ABR.

Discussion

This study’s main goal was to look at the sensory processing patterns of children diagnosed with autism spectrum disorder, ADHD, and normal children using a short sensory profile, visual-evoked potential, and auditory-evoked potential. The research additionally sought to investigate any relation between the clinical severity of each group and the sensory processing patterns, visual-evoked potentials, and auditory-evoked potentials.

Table 1 Sociodemographic attributes of the examined groups

	ASD N= 37 (%)	ADHD N= 41 (%)	Normal N= 43 (%)	Test of significance	Within- group significance
Age (years)					
6–9	28 (75.7)	29 (70.7)	32 (74.4)	MC=2.64	P1=0.446
10–13	8 (21.6)	12 (29.3)	9 (20.9)	P=0.619	P2=0.900
14–16	1 (2.7)	0	2 (4.7)		P3=0.282
Age (years)	8.46±2.69	9.34±2.15	8.63±2.38	F= 1.51 P=0.225	P1=0.109 P2=0.756 P3=0.177
Sex					
Boy	31 (83.8)	29 (70.7)	30 (69.8)	MC=2.48	P1=0.172 P2=0.142
Girl	6 (16.2)	12 (29.3)	13 (30.2)	P=0.289	P3=0.923
Residence					
Rural	24 (64.9)	20 (48.8)	29 (67.4)	MC=2.36	P1=0.153
Urban	13 (35.1)	21 (51.2)	14 (32.6)	P=0.426	P2=0.808 P3=0.08
School placement					
Do not attend	18 (48.6)	8 (19.5)	1 (2.3)		P1=0.009*
Primary	11 (29.7)	27 (65.9)	34 (79.1)	MC=29.99	P2<0.001*
Preparatory	1 (2.7)	2 (4.9)	3 (7.0)	P=0.001*	P3=0.809
Special school	7 (18.9)	4 (9.8)	5 (11.6)		

MC Monte Carlo test, *statistically significant, p1 variation between ASD and ADHD, p2 variation between ASD and normal group, p3 variation between ADHD and normal group. F one-way ANOVA test

Table 2 Intelligence assessment using the raven progressive matrices among studied groups

Raven progress	ASD N= 37 (%)	ADHD N= 41 (%)	Normal N= 43 (%)	Test of significance	Within-group significance
Intelligently superior	5 (13.5)	11 (26.8)	7 (16.3)		P1=0.003*
Definitely above the average in intelligence capacity	11 (29.7)	6 (14.6)	24 (55.8)	Mc=33.19	P2=0.027*
Average intelligence	9 (24.3)	21 (51.2)	9 (20.9)	P<0.001*	P3=0.001*
Definitely below average in intelligence capacity	12 (32.4)	3 (7.3)	3 (7.0)		
Intellectually impaired	0	0	0		

MC Monte Carlo test, *statistically significant, p1 variation between ASD and ADHD, p2 variation between ASD and normal group, p3 variation between ADHD and normal group

Table 3 Clinical parameters among the studied groups

	ASD	ADHD	Normal group	Test of significance	Within- group significance
CARS	37.22±3.89	20.39±3.42	20.37±3.27	F=293.78 P=0.001*	P1<0.001* P2<0.001* P3=0.981
Total Vanderbilt	20.57±5.56	34.05±3.85	21.98±15.76	KW=21.54 P=0.001*	P1=0.001* P2=0.537 P3=0.001*

F one-way ANOVA test, p1 variation between ASD and ADHD, p2 variation between ASD and normal group, p3 variation between ADHD and normal group

*Statistically significant, p1 variation between ASD and ADHD, p2 variation between ASD and normal group, p3 variation between ADHD and normal group

Table 4 Short sensory profile among studied groups

	ASD N= 37 (%)	ADHD N= 41 (%)	Normal N= 43 (%)	Test of significance	Within- group significance
Tactile sensitivity					
Definite difference	22 (59.5)	3 (7.3)	0		P1 < 0.001*
Probable difference	11 (29.7)	13 (31.7)	6 (14.0)	MC=63.67	P2 < 0.001*
Typical performance	4 (10.8)	25 (61.0)	37 (86.0)	P < 0.001*	P3 = 0.02*
Taste/smell sensitivity					
Definite difference	21 (56.8)	7 (17.1)	0 (0.0)		P1 < 0.001*
Probable difference	9 (24.3)	8 (19.5)	5 (11.6)	MC=47.08	P2 < 0.001*
Typical performance	7 (18.9)	26 (63.4)	38 (88.4)	P < 0.001*	P3 = 0.007*
Movement sensitivity					
Definite difference	16 (43.2)	2 (4.9)	0		P1 < 0.001*
Probable difference	12 (32.4)	14 (34.1)	5 (11.6)	MC=33.19	P2 < 0.001*
Typical performance	9 (24.3)	25 (61.0)	38 (88.4)	P < 0.001*	P3 = 0.012*
Under responsive / seek sensation					
Definite difference	26 (70.3)	27 (65.9)	0		P1 = 0.886
Probable difference	9 (24.30)	12 (29.3)	6 (14.0)	MC=85.17	P2 < 0.001*
Typical performance	2 (5.4)	2 (4.9)	37 (86.0)	P < 0.001*	P3 < 0.001*
Auditory filtering					
Definite difference	19 (51.4)	18 (43)	1 (2.3)		P1 = 0.98
Probable difference	10 (27.0)	14 (24.4)	4 (9.3)	MC=44.08	P2 < 0.001*
Typical performance	8 (21.6)	9 (21.9)	38 (88.4)	P < 0.001*	P3 < 0.001*
Low energy					
Definite difference	25 (67.6)	2 (4.9)	0	MC=83.48	P1 < 0.001*
Probable difference	9 (24.3)	7 (17.1)	1 (2.3)	P < 0.001*	P2 < 0.001*
Typical performance	3 (8.1)	32 (78.0)	42 (97.7)		P3 = 0.02*
Visual/ auditory sensitivity					
Definite difference	14 (37.8)	21 (51.2)	1 (2.3)		P1 = 0.490
Probable difference	11 (29.7)	10 (24.4)	3 (7.0)	MC=45.59	P2 < 0.001*
Typical performance	12 (32.4)	10 (24.4)	39 (90.7)	P < 0.001*	P3 < 0.001*
Total					
Definite difference	27 (73.0)	8 (19.5)	0	MC= 1 08.06	P1 < 0.001*
Probable difference	10 (27.00)	25 (61.0)	3 (7.0)	P < 0.001*	P2 < 0.001*
Typical performance	0	8 (19.5)	40 (93.0)		P3 < 0.001*

MC Monte Carlo test, *statistically significant, p1 variation between ASD and ADHD, p2 variation between ASD and normal group, p3 variation between ADHD and normal group

Sensory problems results

Our findings support the literature’s claim that children diagnosed with autism spectrum disorder or attention deficit hyperactivity disorder are more likely than those with normal development to display abnormality in sensory processing [35], but compared with the ADHD group, the autism group showed a noticeably more intense and regular pattern of sensory problems. Our findings are consistent with earlier research that discovered variations in sensory processing styles among individuals diagnosed with ADHD and autism [36, 37]. A study by [1] suggested that children with autism

spectrum disorder exhibit similar sensory processing patterns to those with attention deficit hyperactivity, particularly in the areas of seeking and auditory processing. Our results disagreed with some of the literature that has revealed typical sensory processing patterns for both ADHD and autism [38–40].

A systematic review and meta-analysis could explain this finding, indicating that the visual/auditory and under-responsive/sensory seeking subscales were more severe in ADHD than the other subscales and potentially resolve the contradictory findings in this field’s literature. These findings agree with our current understanding of

Table 5 Visual- and auditory-evoked potential among the studied group

	ASD N= 37(%)	ADHD N= 41 (%)	Normal N= 43 (%)	Test of significance	Within- group significance
Visual-evoked potential					
Right p100	150.85 ± 48.70	119.28 ± 18.06	103.42 ± 5.19	<i>F</i> = 27.09 <i>P</i> = 0.001*	P1 = 0.001* P2 = 0.001* P3 = 0.014*
Left P 100	141.09 ± 32.55	116.51 ± 10.1	103.0 ± 5.91	<i>F</i> = 39.60 <i>P</i> = 0.001*	P1 = 0.001* P2 = 0.001* P3 = 0.002*
Auditory-evoked potential					
Right wave I	1.45 ± 0.10	1.42 ± 0.06	1.39 ± 0.04	<i>F</i> = 5.65 <i>P</i> = 0.005*	P1 = 0.04* P2 = 0.001* P3 = 0.202
Left wave I	1.47 ± 0.09	1.41 ± 0.05	1.41 ± 0.04	<i>F</i> = 10.97 <i>P</i> = 0.001*	P1 = 0.001* P2 = 0.001* P3 = 0.936
Right wave III	3.76 ± 0.15	3.64 ± 0.20	3.49 ± 0.18	<i>F</i> = 23.18 <i>P</i> = 0.001*	P1 = 0.001* P2 = 0.001* P3 = 0.003*
Left wave III	3.68 ± 0.21	3.55 ± 0.23	3.38 ± 0.20	<i>F</i> = 20.38 <i>P</i> = 0.001*	P1 = 0.001* P2 = 0.001* P3 = 0.001*
Right wave V	5.97 ± 0.42	5.51 ± 0.28	5.26 ± 0.39	<i>F</i> = 36.48 <i>P</i> = 0.001*	P1 = 0.051 P2 = 0.001* P3 = 0.082
Left wave V	5.93 ± 0.38	5.54 ± 0.28	5.12 ± 0.28	<i>F</i> = 65.91 <i>P</i> = 0.001*	P1 = 0.001* P2 = 0.001* P3 = 0.001*
Right wave from I to III	2.32 ± 0.14	2.21 ± 0.20	2.13 ± 0.31	<i>F</i> = 6.85 <i>P</i> = 0.002*	P1 = 0.051 P2 = 0.001* P3 = 0.082
Left waves I to III	2.23 ± 0.22	2.14 ± 0.23	1.97 ± 0.21	<i>F</i> = 13.92 <i>P</i> = 0.001*	P1 = 0.092 P2 = 0.001* P3 = 0.001*
Right waves III to V	2.19 ± 0.44	1.96 ± 0.65	1.78 ± 0.44	<i>F</i> = 6.41 <i>P</i> = 0.002*	P1 = 0.046* P2 = 0.001* P3 = 0.116
Left waves III to V	2.22 ± 0.38	1.99 ± 0.31	1.75 ± 0.26	<i>F</i> = 21.59 <i>P</i> = 0.001*	P1 = 0.003* P2 = 0.001* P3 = 0.001*

*statistically significant, *p*1 variation between ASD and ADHD, *p*2 variation between ASD and normal group, *p*3 variation between ADHD and normal group

the features of ADHD. The SSP describes behaviors such as reaching for objects and people, haphazardly switching between tasks, and seeking mobility as under-responsive and sensory-seeking [5].

As we know, the diagnostic criteria for ADHD include behaviors like fidgeting or wriggling frequently, having trouble staying sat, having trouble maintaining attention, or failing to finish activities [16]. As a result, there is an overlap between behaviors classified as sensory seeking or under-responsive and behaviors classified as traits of ADHD. One weakness of this study was the overlap in the measures employed to evaluate the symptomatology and patterns of sensory processing.

Similarly, there was a strong correlation between auditory filtering, ADHD, and attention. The capacity to instinctively and unintentionally block out irrelevant sounds in our environment is known as “auditory filtering,” while the deliberate effort to focus on what is important to us is known as “attention” [41].

Therefore, if the automated filtration of sound-based input is diminished, the system of active attention will be subjected to more information, making it harder to focus on the most prominent stimuli in the surroundings. Prior research on auditory filtering in ADHD has not revealed any group distinctions when compared to individuals without the diagnosis [42, 43]. Nonetheless, other

Table 6 Correlation between sensory profile and clinical severity among ASD group

ASD		CARS
Tactile sensitivity	r	-0.392*
	p-value	.017
Taste–smell	r	-0.481**
	p-value	.003
Movement sensitivity	r	-0.398*
	p-value	.015
Under responsive	r	-.053
	p-value	0.755
Auditory filtering	r	-.374*
	p-value	.023
Low energy	r	-.503**
	p-value	.002
Visual auditory	r	-.090
	p-value	0.596
Total	r	-0.448**
	p-value	.005

*statistically significant, p1 variation between ASD and ADHD, p2 variation between ASD and normal group, p3 variation between ADHD and normal group

Table 7 Correlation between clinical severity and evoked potential in ASD group

		CARS
RT P100	r	0.256
	p	0.126
LT P100	r	0.324
	p	.051
RT wave 1	r	.078
	p	0.646
LT wave 1	r	0.206
	p	0.222
RT wave V	r	0.285
	p	.087
LT wave V	r	0.285
	p	.087
RT waves III–V	r	0.285
	p	.087
LT waves III–V	r	0.285
	p	.087

research has linked concentration issues to auditory filtering [44, 45].

Regarding the autism spectrum disorder group, 73% were determined to have definite sensory processing problems, 27% had possible sensory processing problems, and no one had a typical performance. This result aligns with a study indicating that, according to the sensory profile, 42–95% of autistic children have problems

Table 8 Correlations between subtypes of ADHD and short sensory profile in the ADHD group

		Inattention	Hyperactive	Combined
Tactile sensitivity	r	-0.399	0.123	0.285
	p	.010	0.442	.071
Taste–smell	r	-0.399	-.027	0.287
	p	.010	0.867	.069
Movement sensitivity	r	-0.396	0.156	0.254
	p	.010	0.330	0.109
Under responsive	r	.075	.088	-0.152
	p	0.643	0.582	0.344
Auditory filtering	r	-.065	-.098	.019
	p	.689	0.544	0.906
Low energy	r	-0.283	0.138	.065
	p	.074	0.390	0.685
Visual auditory	r	-0.124	-0.116	0.164
	p	0.440	0.472	0.307
Total	r	-0.162	-.091	0.160
	p	0.311	0.572	0.317

Table 9 Correlations between subtypes of ADHD and evoked potential in ADHD group

		Inattention	Hyperactive	Combined
RT P100	r	.068	0.259	-0.295
	p	0.673	0.102	.061
LT P100	r	.068	0.259	-0.295
	p	0.673	0.102	.061
RT wave V	r	-.023	0.214	-.064
	p	0.889	0.180	0.689
LT wave V	r	-.023	0.214	-.064
	p	0.889	0.180	0.689
RT waves III–V	r	-.023	0.214	-.064
	p	0.889	0.180	0.689
LT waves III–V	r	-.013	.070	.057
	p	0.936	0.663	0.725

with sensory processing, a parent-report measure. In addition, the results of our research are consistent with a study conducted by [46] on sensory processing and attention patterns in children with autism spectrum disorders and children with sensory processing disorders which found that the ASD group scored 95.8% had either probable or definite sensory processing problems [13, 47].

Regarding the ADHD group, 80.5% were determined to have either a definite sensory problem or a probable sensory problem, and 19.5% (n = 8) had a typical performance. These results aligned with other studies on ADHD and deficiencies in sensory processing [12, 48–52]. In line with a study by [53] that found a

considerable variation in the total score of sensory processing between the group of ADHD and the typical developing group, our study additionally found a significant difference in short sensory profiles between the ADHD group and typically developed children.

This study showed that the total most affected sensory processing in ADHD was in under-responsive/seeks sensation which is consistent with [39, 54, 55] who reported that individuals with ADHD obtained high scores in the sensation-seeking component which indicates a tendency to seek opportunities to enhance sensory experiences that are perceived as pleasurable. However, these individuals easily become bored in unstimulating environments and tend to seek stimuli that may be distracting to others [54].

Visual-evoked results

Using pattern-reversal visual-evoked potential (VEP), we looked at neuronal transmission in the visual system of children with ASD and of controls, who were the same age. The major metric for comparison was the p100 latency.

In the current study, the ASD group in our study displayed a more notable delay in VEP contrasted with the group of ADHD and the group of normal children (Rt eye p100 latency in ASD was 150.85 ± 48.70 vs 119.28 ± 18.06 in ADHD vs 103.42 ± 5.19 in normal, left p100 latency 141.09 ± 32.55 vs 116.51 ± 10.1 vs 103.0 ± 5.91). These findings coincide with those obtained by [17, 33, 56] who found that P100 latencies were substantially prolonged in the group of autism spectrum disorder contrasted with the group of normal children, and this result could be attributed to slower neural communication and altered connectivity within the visual pathways, which might contribute to the diminished social interaction seen in autism spectrum disorder [17].

A study by [57, 58], which found that latency measures failed to determine diversity between ASD-subjects for the P100-components, contradicts our findings. The size of the windows utilized to obtain these measures may be the cause of the ambiguous variations between the two groups and their latency.

Our results showed that there was a statistically considerable variation between the group of ADHD and the normal group; however, [59] found that the latency could not provide a statistically considerable variation between the two groups, which could be assigned to the limited size of the sample in which he only conducted 12 cases of ADHD and 12 normal subjects; in contrast, our study was performed on 41 subjects with ADHD and 43 normal subjects.

Auditory-evoked potential results

Regarding ABR, we determined the inter-wave intervals of waves I–III and III–V in addition to the relative latencies of waves I, III, and V. This study compared the autistic group with children with ADHD and typically developing children.

Regarding children diagnosed with autism spectrum disorder group, we found that the absolute latency of waves I, III, and V and the inter-wave intervals of I–III and III–V significantly deviated from the norms in the ASD group. These results show that children diagnosed with autism spectrum disorder have central auditory nervous system dysfunction or immaturity.

In harmony with what we found, [23] revealed that in comparison to clinical norms, all absolute latencies and IPLs were noticeably longer in the ASD group, excluding IPL III–V [22] which is inconsistent with our study which found delays in inter-wave interval III–V.

[60] assessed auditory-evoked potentials in a group of children with autism. The quantitative data analysis revealed that only the ABR's latencies of waves III and V and interpeak I–III and I–V have considerable variations between the ASD and the control groups.

[61, 62] revealed that the latency of wave V and waves I–V IPLs was notably delayed in the group of ASD. In a similar vein, [63] found that statistical analysis was performed on the findings. The research revealed that the absolute latency of waves III and V on the right ear, those of waves I and III on the left ear, and the right and left ear's interpeak latencies I–III and I–V deviated considerably from the norm. Inconsistent with our results, [64] discovered that there were no appreciable variations in ABR amplitude or latency between the ASD and control groups.

ABR prolongation in ASD may be explained by an underlying neuropathology, although this is unknown. One possible explanation is that infants with ASD have slower rates of myelination in their auditory systems, which could lead to longer wave V latencies; nevertheless, some data indicates that these delays are significant [65–68]; others claim that white matter growth is accelerated in ASD [69, 70].

According to various contemporary theories of ASD neurophysiology, infants with ASD may display temporary abnormalities during early, crucial developmental stages that eventually normalize (e.g., early brain over-growth) [71–73].

Regarding the ADHD group, we found that only left waves III and V latency as well as left interpeak latency between I–III and III–V were significantly away from the norms. Comparable to a study by [74] which discovered longer latencies of waves III and V in children with attention deficit disorder (ADD) and a considerable variation

in the mean inter-peak latency between waves I–III and I–V between ADD subjects and controls, these results hold similar significance. These findings appear to suggest a deficiency in central auditory process activation as well as aberrant brainstem transmission.

Another study by [75] discovered extended latencies of wave V in both sexes and of wave III in females of the study group. Inconsistent with our study [76], found all children had typical findings of ABR and typical latency of wave V. Another study conducted by [77] did not find considerable variations in the absolute peak latencies, inter-peak latencies.

Correlations results

Children with more severe autism in this study showed higher sensory deficiencies. There was a negative relation between the SSP total and all subscale scores and CARS. It is crucial to recall that the more aberrant sensory processing, the lower the sensory pProfile score is when analyzing the correlation analyses between the CARS and the sensory profile. Conversely, a lower CARS score is connected to a less in severity of autism. Thus, a positive association suggests that either a sensory processing improves, autism gets worse, or the opposite occurs, with autism getting better. A negative connection indicates that autism is more severe when sensory processing deteriorates or less severe when sensory processing improves.

The obtained results are in harmony with those detected in many other studies in which the severity of ASD was linked to the severity of sensory deficits [78–81]. Previous studies, however, did not find a statistically significant diverse in frequent sensory complaints between low- and high-functioning autism subgroups [82].

As the sensory processing data, as well as autism severity, were reported by parents (or teachers), this could cause the respondent to rank behaviors similarly across the scales. The latest research publication recommends a present tendency to utilize other measures in addition to psychometric tools to assess sensory processing and investigate how it correlates with autism severity, even though this was the case in the current research (we investigated the link between the clinical severity of ASD and visual and auditory-evoked potentials), but we did not find a statistically significant correlation, and these findings agree with the study conducted by [17, 33].

This study found that there was no considerable relation between the severity of ADHD as well as sensory problems; in other words, there were no discernible differences across the types of ADHD either inattention or hyperactivity and sensory issues—in this investigation, consistent with the study conducted by [83]. However, the current study is inconsistent with [84] which

revealed an extremely substantial positive association between the frequency of reported sensory processing issues and the number of ADHD characteristics. Despite earlier research suggesting hyperactive children may have greater challenges with sensory processing [85–87]. Further research with larger sample sizes should further investigate if there is a distinct SPD expression for every form of ADHD.

A higher grade of ADHD was linked with a greater rate of sensory problems in all modalities. However, an accurate recognition of the link between SPD and ADHD has proven difficult to come by [50, 52]. Furthermore, there has not been enough discussion in the study literature about whether children with various forms of ADHD have distinct sensory processing capacities.

The results of our research found that there was no considerable relation between the subtype of ADHD and visually evoked potential, and these results are consistent with research conducted by [88] and not in a similar vein to the study conducted by [89] who discovered a favorable correlation between P300 latency levels and the ADHD rating scale's inattention subscale scores. However, the disparity in the results could be explained by the different visual-evoked potential and scales used to assess ADHD in our investigation and the aforementioned study. Our study used pattern reversal, while the aforementioned study used event-related evoked potential.

Our study did not reveal a significant correlation between the severity of ADHD and auditory-evoked potential, and these results are inconsistent with the study that found a significant correlation between ADHD main symptoms and loud-dependent auditory-evoked potential [90]. There has been evidence of a relationship between evoked potential and impulsivity, inattention, and both. More impulsive people have also been discovered to have increased r LDAEP levels. [91] and reflect behavioral suppression and emotional sensitivity [92]. In a recent study, evoked potential was found to be unrelated to the hyperactive subscale but highly linked with the inattention subscale and symptoms of ADHD in adults with depression [93].

Evaluation of the child's sensory functioning helps us in the therapeutic implementation of sensory-based interventions. When it comes to intervention practices like Ayres Sensory Integration Therapy, the data gathered from the assessment is then utilized to develop an individually customized intervention program of sensory-rich experiences that are intended to either permanently support sensory processing or improve future integration of sensory information [94].

Strengths

A noteworthy aspect of our research is that we employed visual-evoked potential as well as auditory-evoked potential for all three groups and compared children with ASD not just with the TD group but also with age-matched children with ADHD.

Limitations

First, the SSP measures, widely used in clinical practice and research, are all parent-report measures, making them vulnerable to shared method variance. Second, SSP items do not distinguish between context (i.e., social vs. non-social), and some may assess hyperactivity and attentional issues, potentially explaining the correlation between ADHD symptoms and the wide age range of the sample. Third, larger sample sizes in future research would allow for the use of stratification by some variables, including age, to analyze VEP measurements and frequency bands [95]. Finally, one of our limitations is that we did not have a group of medicated children to compare with non-medicated ones. This is because we included children in the ASD and ADHD groups who were not on medication, so the severity of the disease may have been higher than in the overall patient population.

Conclusion

Sensory processing issues are more common in children with ASD and ADHD than in typically developed children; therefore, we recommend basic testing, follow-up, and encouragement of modifications to therapeutic intervention.

Abbreviations

ASD	Autism spectrum disorder
ADHD	Attention deficit hyperactivity disorder
SP	Sensory processing
SPD	Sensory processing difficulties
VEP	Visual-evoked potential
ABR	Auditory brainstem response
CARS	Childhood Autism Rating Scale
DSM5	<i>Diagnostic and Statistical Manual of Mental Disorders</i>
SSP	Short sensory profile
VADPRS	Vanderbilt ADHD Diagnostic Parent Rating Scale
TD	Typically developing

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Authors' contributions

AS collected the data and interviewed the patients, KE performed evoked potential to children, and ME contributed to writing the manuscript. ME contributed to writing the manuscript. MA revised and edited the manuscript. ST revised the manuscript, and all authors read and approved the final manuscript.

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Availability of data and materials

The corresponding author can provide the datasets used and analyzed in the current study upon reasonable request.

Declarations

Ethics approval and consent to participate

Ethical approval for this research was granted by the Ethical Committee of the Faculty of Medicine, Mansoura University, following the Code of Ethics of the World Medical Association, as stated in the Declaration of Helsinki (MD.21.09.528). Before their participation, all participants' guardians were presented with a transparent description of the research's objectives and comprehensive details of the questionnaire. Every participant's parent provided informed written consent particularly mothers, to ensure their understanding and voluntary agreement to participate in the study. Participants were assured of the confidentiality of their information and explicitly educated about their right to decline participation or leave the study whenever they wanted without facing any repercussions. No financial incentives were provided to participants for their involvement in the research.

Consent for publication

The subjects gave their permission for publication.

Competing interests

The authors declare that they have no competing interests.

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