Communication skills, sensory integration functions, and auditory brainstem response: findings in a group of Egyptian children with autistic features

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Objectives

The aim of this work was to study the correlation between communication skills, sensory integration dysfunction, and auditory brainstem response (ABR) findings in a group of children with autistic features in order to gain a better understanding of some of the communication deficits commonly encountered in these children.

Methods

The study was conducted on 25 Egyptian children with autistic features and 25 age-matched and sex-matched typically developing children. All the children's age ranged from 4 to 9 years. Each child was subjected to the following: history taking, communication assessment, sensory integration dysfunction questionnaire, psychometric evaluation, the Childhood Autism Rating Scale, basic audiological evaluation, and assessment of ABR (20 and 70 c/s). The results obtained from the two groups were then compared. In addition, correlation studies of all the results obtained were carried out.

Results

There were significant differences between the two groups under study in terms of communication skills, sensory integration dysfunction, and ABR waves III, III–V, V (20 c/s), I–V, and V′ (70 c/s). There was a significant negative correlation between ABR waves I and III and behavior, intentionality, capacity of symbols, reasoning, and total communication scores. There was a significant negative correlation between ABR waves III and V and forms, behaviors, intentionality, capacity of symbols, imitation, and total communication scores. There was a significant positive correlation between auditory sensory dysfunction scores and ABR wave V and waves III–V. There was a significant negative correlation between sensory integration dysfunction and intelligent quotient and communication skills. There was a significant positive correlation between sensory integration dysfunction scores and the severity of autism.

Conclusion and recommendations

Some of the communication difficulties shown by children with autism might be related to sensory integration dysfunction. Auditory defects in autism may involve lower levels of neural transmission. Reducing sensory integration deficits can aid in minimizing some of the features commonly encountered in children with autism. This would also aid in further development of their sociocommunication skills. ABR, as an objective tool, may be used as a prognostic indicator.

Keywords:

auditory brainstem response, autism, communication skills, sensory integration dysfunction

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Introduction

According to the *Diagnostic and Statistical Manual of Mental Disorders*, 4th ed. (DSM-IV) [1], autism is characterized by qualitative impairments in social interaction (at least two features); marked impairment in the use of multiple nonverbal behaviors, failure to develop peer relationships, lack of spontaneous seeking to share enjoyment with other people, and lack of social or emotional reciprocity, in addition to qualitative impairments in communication as manifested by at least one of the following: delay in the development of spoken language, marked impairment in the ability to initiate or sustain a conversation with others, stereotyped and repetitive use of language, lack of varied, spontaneous make-believe play, and restricted repetitive stereotyped patterns of behavior, interests, and activities with an onset before 3 years of age.

There is enormous heterogeneity in terms of communication skills among autistic children [2]. Nevertheless, children with autism usually show common abnormalities for example, immediate and delayed/deferred echolalia [3].

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They usually have difficulties with pronouns and may produce a lot of jargon and/or neologism [4,5]. Assessment of communication skills in children having difficulties should include evaluating the child's ability to request his needs as well as his vocal and motor imitation skills [6].

Among the features commonly encountered in autism is sensory integration dysfunction [7,8] to the extent that some authors believe that sensory perceptual assessment is vital in any autism communication profile [9]. Sensory integration is the ability to take information through the senses, to place it together with prior information, memories, and knowledge stored in the brain, and to make a meaningful response [10]. In children with sensory integration dysfunction, some parts of the brain do not receive the sensory information they need to serve their function [11].

Sensory integration disorders can be classified into modulation and discrimination disorders. Modulation disorders can take the form of under-reaction, over-reaction, or fluctuation between the two extremes. In contrast, discrimination disorders can be defined as the ability to differentiate touch, force, and information about body position in space [12].

There is increased evidence that in some individuals with autism, lack of adequate language and communication skills may be related to issues other than social-cognitive abilities [13]. Among these factors is abnormal auditory pathway functioning. This can act as a major contributing factor to inhibition of typical language development in children with autism. Abnormalities in the auditory pathway can occur at different levels of the auditory pathway, from the cochlea [14] to the cortex [15], leading to negative effects on communicative competence in autism.

Some autistic persons have been reported to have brainstem dysfunction [16]. Auditory-evoked potentials refer to the brain responses induced by the presentation of auditory stimuli. They are time-linked to certain specified events [17]. They consist of a sequence of positive and negative deflections or peaks that are named according to their polarity (positive/negative) and latency (timing in relation to stimulus onset), their serial order, or cognitive meaning [18]. The most commonly used auditory-evoked potential methodology is the auditory brainstem response (ABR); it can provide an objective estimate of the auditory brainstem pathway particularly in very young and/or uncooperative participants [19].

An ABR recording consists of five to seven waves. The most commonly studied ABR responses are waves I, III, and V. Wave I is generated in the first afferent auditory neuron, in the distal part of the cochlear nerve. Wave III is generated in the ipsilateral cochlear nuclei and wave V in the lateral lemniscus, but with contributions from multiple anatomical structures [20].

Autism encompasses many features including language difficulties, social difficulties, and repetitive movements [21]. There is growing evidence that sensory integration and the auditory brainstem operate differently in autism. These abnormalities, along with reduced mental skills and the severity of the autism itself, can negatively influence communication skills.

Objectives

The aim of this work was to study the correlation between communication skills, sensory integration dysfunction, and ABR findings in a group of children with autistic features in order to gain a better understanding of some of the communication deficits commonly encountered in these children.

Patients and methods

The tested participants included 50 Egyptian children in the age group of 4–9 years. There were 25 were healthy typically developing children free from any history of language difficulties; these were included in the Control group and the other 25 were children previously diagnosed with autistic features according to the DSM-IV-TR criteria [1].

These were included in the Autism group. Children in the Autism group were selected from the Phoniatric outpatient clinic of Kasr El-Aini Hospital and the Hearing and Speech Institute. This research was conducted between October 2007 and December 2008 and the study protocol was approved by the Otolaryngology Department Council of Cairo University. A written consent to participate in this research was obtained from the children's parents before commencement of the study. Information on age, developmental history, and medical reports were obtained through an interview that had been carried out with the parents before the start of the study. Thereafter, each child under study was subjected to the following:

(1) *Psychometric evaluation*: The intelligent quotient (IQ) of each child was calculated using the Stanford Binet Intelligence Scale [22]. The distribution of children with autism according to IQ was as follows: 50% mild mental retardation, 40% borderline IQ, 5% below average IQ, and 5% average IQ.
(2) *The Childhood Autism Rating Scale* (*CARS*) [23]: CARS was used to diagnose and rate the severity of autism. The distribution of autistic patients according to CARS was as follows: 50% had mild autistic features and 50% had moderate autistic features.
(3) *Assessment of communication skills* (designed in the current study): Communication assessment included evaluation of the child's signals, forms, requesting abilities, behavior, intentionality, readability of communication behaviors, capacity of symbols and reasoning, vocal and motor imitation, and reasoning (Appendix 1).
(4) *Sensory Integration Dysfunction Questionnaire* (designed in the current study): The sensory integration dysfunction questionnaire included questions addressing dysfunctions in auditory, visual, olfactory, vestibular, and tactile sensations (Appendix 2).
(5) *Basic audiological assessment*: Play audiometry using warble tones was performed at frequencies of 0.5, 1, 2, and 4 kHz using a dual-channel clinical audiometer (AC 40; Interacoustics, Denmark) with TDH 39 earphones. Immittancemetry including tympanometry and acoustic reflex threshold measurement (ipsilateral and contralateral at frequencies 0.5, 1, 2

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and 4 kHz) was also performed using an Interacoustic AZ-26 middle ear analyzer (Interacoustics) calibrated according to the ISO standards, Assens, Denmark. Immittancemetry was performed to exclude children with middle ear pathologies.

(6) *ABR*: Auditory-evoked potentials in the form of an ABR using a filter setting of 100–1500 Hz, a time window of 10 ms, a stimulus in the form of a rarefaction click with a duration of 100 ms, a sweep count of 2000, and an intensity of 100 dB nHL were used. Electrodes were mounted with the recording electrode on the forehead, the reference electrode on the ipsilateral mastoid, and the ground electrode on the contralateral mastoid. The total test duration was around 15 min. The following measures were obtained: the absolute latencies of waves I, III, and V at 20 c/s, relative interpeak latencies of I–III, III–V, and I–V at 20 c/s, absolute latency of wave V at 70 c/s, amplitude of wave V at 20 and 70 c/s, and latency shift and wave V at 70 versus 20 c/s. The 'Vivosonic digital processing technique' was used. It is a wireless system for electrophysiological assessment and hearing screening whose main platform is scalable and hence did not require sedation of patients. ABR was carried out using the Vivosonic brain-evoked response audiometer model V-500 (BDT version 4; Vivosonic Inc., Toronto, Canada) with ER-3A insert earphones.

Statistical methods

An IBM-compatible personal computer was used to store and analyze the data. Calculations were carried out using statistical software package for the social sciences (SPSS, version 10; Armonk, New York, USA). Data were tabulated and statistically analyzed to evaluate differences between the groups under study in terms of various parameters. Correlations were performed between the studied parameters. Statistical analysis included the arithmetic mean, SD, Hypothesis Student's (t) test, and Pearson's correlation coefficient. The correlation between variables was determined using the Pearson correlation test. This test determines whether the changes in one variable are accompanied by a corresponding change in the other variable. A significant correlation may be positive, indicating that the change in the two variables is in the same direction, or negative, indicating that the change in the two variables is in the opposite direction. Results were considered nonsignificant if P value was greater than 0.05 and significant if P value was less than 0.05.

Results

Play audiometry showed within-normal warble tone thresholds at all tested frequencies in autistic children and controls, with no significant differences ($P > 0.05$).

Significant differences were found between the two groups under study in terms of communication skills Table 1 and sensory integration dysfunction Table 2, and ABR wave III, waves III–V, wave V, waves I–V, and wave V′. However, nonsignificant differences were found in terms of wave I, waves I–III, V amplitude, V′ amplitude, and V–V′ latency differences Table 3.

Correlation studies

A significant negative correlation was found between waves I and III and each of behavior, intentionality, reasoning,

Table 1 Comparison of the Autism group and the Control group in the scores obtained for communication skills

	Mean ± SD			
Communication skills	Autism group	Control group	t-test	Significance
Signals and their meanings	17.601 ± 5.553	32.121 ± 0.881	12.91	S
Forms used to indicate specific needs/requests	34.725 ± 8.947	66 ± 0.00	17.48	S
Behaviors	3.644 ± 1.150	6 ± 0.00	10.26	S
Intentionality	6.206 ± 1.00	12.282 ± 0.737	24.47	S
Readability of communication behaviors	3.407 ± 1.354	7.563 ± 0.507	14.39	S
Capacity of symbols	1.125 ± 0.332	1.526 ± 0.510	3.288	S
Imitation	1.483 ± 1.388	4.443 ± 0.507	10.02	S
Reasoning	1.202 ± 1.00	4.526 ± 0.510	14.79	S
Total	69.361 ± 19.571	134.441 ± 3.453	16.36	S

Significant (S, $P < 0.05$).

Table 2 Comparison of the sensory integration dysfunction score obtained by the Autism group and the Control group

	Mean ± SD			
Sensory dysfunction score	Autism group	Control group	t-test	Significance
Auditory	6.402 ± 1.384	1.646 ± 0.757	15.08	S
Visual	5.925 ± 1.320	1.646 ± 0.757	14.06	S
Olfactory	3.804 ± 1.00	1.00 ± 0.00	13.00	S
Vestibular	4.526 ± 1.159	1.443 ± 0.51	12.17	S
Tactile	4.526 ± 1.159	1.443 ± 0.05	12.17	S
Total	25.163 ± 5.900	7.322 ± 2.358	14.04	S

Significant (S, $P < 0.05$).

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capacity of symbols, and total communication scores and between waves III and V and each of communication forms, behaviors, intentionality, capacity of symbols, imitation, and total communication scores Tables 4 and 5. However, a significant positive correlation was found between auditory dysfunction scores and each of wave V and waves III–V Tables 6 and 7.

A significant negative correlation was found between the total sensory integration dysfunction scores and IQ and communication skills. However, a significant positive correlation was found between the total sensory integration dysfunction scores and CARS scores Tables 8 and 9.

Discussion

Impairment in communication is one of the core symptoms in autism [24]. Communication is highly dependent on the input that is received from the surrounding environment and the way a person responds is highly dependent on what is perceived. Children with

Table 3 Comparison between the auditory brainstem response latency (ms) and amplitude (μV) obtained by the Autism group and the Control group

ABR Mean	Mean ± SD Autism group	Mean ± SD Control group	*t*-test	Significance
20 c/s				
Wave I	1.381 ± 0.159	1.366 ± 0.119	0.37	NS
Wave III	3.585 ± 0.192	3.476 ± 0.128	2.37	S
Wave V	5.489 ± 0.317	5.218 ± 0.139	3.92	S
Wave I–III	2.180 ± 0.229	2.258 ± 0.493	0.72	NS
Wave III–V	1.940 ± 0.240	1.754 ± 0.189	3.04	S
Wave I–V	4.123 ± 0.272	3.951 ± 0.210	3.95	S
70 c/s				
V amplitude	0.630 ± 0.1611	0.621 ± 0.829	0.26	NS
Wave V′	5.757 ± 0.187	5.557 ± 0.118	4.52	S
V′ amplitude	0.471 ± 0.202	0.556 ± 0.113	0.25	NS
V–V′ latency differences	0.267 ± 0.291	0.340 ± 0.077	0.23	NS

ABR, auditory brainstem response.
Significant (S, $P<0.05$).

Table 4 Correlation coefficient between auditory brainstem response and age, intelligent quotient, and Childhood Autism Rating Scale

	Age correlation (*r*)	Significance	IQ correlation (*r*)	Significance	CARS correlation (*r*)	Significance
20 c/s						
Wave I	−0.144	NS	−0.379	NS	0.305	NS
Wave III	−0.122	NS	−0.381	NS	0.371	NS
Wave V	−0.169	NS	−0.315	NS	0.252	NS
Wave I–III	−0.147	NS	−0.033	NS	0.005	NS
Wave III–V	−0.334	NS	−0.202	NS	0.172	NS
Wave I–V	−0.178	NS	−0.138	NS	0.137	NS
V amplitude	0.123	NS	0.365	NS	−0.275	NS
70 c/s						
Wave V′	−0.232	NS	−0.393	NS	0.293	NS
V′ amplitude	0.327	NS	0.245	NS	−0.251	NS
V–V′ latency difference	0.331	NS	0.080	NS	0.085	NS

CARS, Childhood Autism Rating Scale; IQ, intelligent quotient; −, negative correlation.
Significant (S, $P<0.05$).

Table 5 Correlation coefficient between auditory brainstem response findings (20 c/s) and communication scores

Communication skills	20 c/s I	III	V	I–III	III–V	I–V	V amplitude
Signals and their meanings	−0.288	−0.200	−0.202	−0.151	−0.295	−0.097	0.115
Forms	−0.324	−0.247	−0.317	−0.338	.424*	−0.173	0.0178
Behaviors	−0.37	−0.233	−0.383	−0.527*	−0.493*	−0.218	0.137
Intentionality	−0.0353	−0.108	−0.258	−0.531*	−0.401*	−0.055	0.220
Readability of communication behaviors	−0.184	−0.384	−0.168	−0.221	−0.064	−0.150	0.115
Capacity of symbols	−0.291	−0.137	−0.270	−0.460*	−0.431*	−0.171	0.119
Imitation	−0.353	−0.108	−0.258	−0.031	−0.401*	−0.055	0.170
Reasoning	−0.108	−0.055	−0.272	−0.484*	−0.364	−0.0173	0.65
Total	−0.337	−0.250	−0.291	−0.465*	−0.486*	−0.154	0.156

−, negative correlation.
*Significant ($P<0.05$).

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autism usually do not respond in a way that is expected from them. They have different sense, perception, abilities, and thinking systems (SPATS), which, in turn, negatively influence their learning, behavior, and language development [9].

Receptors of different senses are located in the peripheral nervous system. However, it is believed that the sensory integration problems stem from neurological dysfunction in the central nervous system. This explains how sensory integration techniques can facilitate attention, awareness, and reduce overall arousal [12]. The current study found significant differences between the Control group and the Autism group in terms of auditory, visual, olfactory as well as vestibular dysfunction (Table 2). Some of the children with autism showed features suggestive of hypersensitivity, whereas others showed features suggestive of hyposensitivity. The former was manifested in the form of unjustified defensiveness or hyper-responsiveness (over-reaction) to sensory information that most individuals would consider harmless, for example, covering the ears on hearing a loud noise or extreme intolerance to certain phone rings. Previous researches have also reported similar findings; autistic children were found to frequently cover their ears in the absence of any disturbing sound, which, in turn, reflected their hypersensitivity [10]. This might be secondary to either auditory overload , that is, there are too many stimuli entering one or more of the child's auditory system, or it might be due to a highly aroused nervous system that cannot differentiate between threatening and non-threatening inputs [25].

Table 6 Correlation coefficient between auditory brainstem response findings (70 c/s) and communication scores

	70 c/s		
Communication skills	V′	V′ amp	V–V′
Signals and their meanings	−0.264	0.302	0.74
Forms	−0.311	0.296	0.172
Behaviors	−0.275	0.295	0.226
Intentionality	−0.252	0.195	0.136
Readability of communication behaviors	−0.225	0.234	0.132
Capacity of symbols	−0.006	0.207	0.270
Imitation	−0.252	0.136	0.138
Reasoning	−0.073	0.076	0.089
Total	−0.292	0.320	0.160

−, negative correlation.
Significant ($P<0.05$).

For other children, the dysfunction seemed to be more toward the hyposensitive side; children seemed to frequently seek sounds, for example, enjoy listening to the cracking of a candy wrap close to their ears. Other parents reported that their autistic children frequently failed to respond to their names despite their ability to immediately respond when their favorite song is played two rooms away, what is commonly referred to as selective hearing.

Some autistic children were reported to be very irritable, difficult to soothe, emotionally labile, and hypersensitive to touch, whereas others were reported to frequently seek tactile sensations, biting others, inappropriately hugging them, or touching their cheeks. Others showed features suggestive of a hyposensitive olfactory system; they tended to use excessive smell to explore odors of various objects.

However, others seemed hypersensitive, reacting negatively to smell, vestibular, or tactile stimulation. Such sensory problems may be the underlying reason for behaviors such as rocking, spinning, and hand flapping. Some children were reported to flicker objects in front of their eyes or enjoyed being in dark places, reflecting hypersensitive or hyposensitive vision, respectively.

From the previously mentioned observations, it could be deduced that children with autism usually show features suggestive of sensory integration dysfunction. However, they can differ considerably in their sensory dysfunction patterns. Treatment of sensory disorders can help in reducing self-stimulatory behavior in such children. Yet, the intervention program has to be tailored according to the sensory needs of each child as what is appropriate for one child may be useless or even harmful to another.

The significant negative correlation obtained between sensory integration dysfunction and communication skills (Table 9) implies a relationship between sensory dysfunction and communication difficulties; the more the sensory dysfunction, the worse the communication difficulties are expected to be. This might be due to the attention problems and regulatory disorders that usually occur secondary to sensory integration dysfunction, hindering typical communication development in children with autism; communication development requires considerable attention from the child's side and the ability to attend to a task depends on the ability to screen out or inhibit unnecessary information, background noise, or visual distracters. Children with sensory integration dysfunction face huge difficulties with respond-

Table 7 Correlation coefficient between auditory brainstem response latencies and amplitudes (20 c/s) and sensory integration dysfunction scores

ABR 20 c/s	Auditory sensory dysfunction score	Visual sensory dysfunction score	Olfactory sensory dysfunction score	Vestibular sensory dysfunction score	Tactile sensory dysfunction score	Total sensory dysfunction score
Wave I	0.353	0.184	0.291	0.335	0.353	0.337
Wave III	0.294	0.064	0.331	0.291	0.279	0.386
Wave V	0.401*	0.168	0.270	0.334	0.258	0.291
Wave I–III	0.221	0.031	0.061	0.120	0.031	0.065
Wave III–V	0.602*	0.384	0.137	0.376	0.108	0.205
Wave I–V	0.218	0.150	0.171	0.055	0.055	0.145
V amplitude	−0.226	−0.292	−0.252	−0.272	−0.272	−0.268

ABR, auditory brainstem response; −, negative correlation.
*Significant ($P<0.05$).

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Table 8 Correlation coefficient between auditory brainstem response latencies and amplitudes (70 c/s) and sensory integration dysfunction scores

ABR 70 c/s	Auditory sensory dysfunction score	Visual sensory dysfunction score	Olfactory sensory dysfunction score	Vestibular sensory dysfunction score	Tactile sensory dysfunction score	Total sensory dysfunction score
Wave V′	0.244	0.078	0.035	0.139	0.224	0.242
V′ amplitude	−0.260	−0.158	−0.195	−0.251	−0.251	−0.228
V–V′ latency difference	0.137	0.118	0.136	0.086	0.086	0.115

ABR, auditory brainstem response; −, negative correlation.
Significant ($P<0.05$).

Table 9 Correlation coefficient between sensory integration dysfunction scores, intelligent quotient, Childhood Autism Rating Scale, and communication skills scores

	Total sensory integration score
Intelligent quotient correlation (*r*)	−0.928*
CARS correlation (*r*)	0.983*
Communication skills correlation (*r*)	−0.975*

CARS, Childhood Autism Rating Scale; −, negative correlation.
*Significant ($P<0.05$).

ing to or registering sensory information without this screening ability and are considered to be easily distractible, hyperactive, or uninhibited. These children constantly seek orienting sensory input that others ignore. Furthermore, children with sensory integration disorders often have regulatory disorders. This can be manifested in the form of difficulty establishing appropriate sleep and eating patterns or over-reaction to ordinary environmental stimuli. Insufficient sleep along with easy distractibility can, in turn, aid in reducing the benefit a child with autism can receive from the surrounding environment.

Sensory integration occurs in the nervous system and is generally believed to take place in the midbrain and brainstem levels. It requires complex interactions between coordination, attention, arousal system, autonomic functions, emotions, memory, as well as cognition [26]. This might partially explain the significant positive correlation that was found between the auditory sensory dysfunction score and each of ABR wave V and ABR waves III–V Table 7.

A significant negative correlation was found between IQ and sensory integration dysfunction (Table 9). This implies that the lower the IQ, the more the features of sensory integration dysfunction, a fact that should be taken into consideration while establishing a differential diagnosis between mental deficiency and autism as some of the children with a low IQ may exhibit some of the sensory features commonly encountered in children with autism.

However, a positive correlation was found between sensory integration dysfunction scores and CARS scores (Table 9), that is, the greater the severity of autism, the more frequent the sensory integration dysfunction features. Similar findings were obtained in previous studies that revealed a significant correlation between sensory integration disorders and autistic features [24,27].

These findings suggest that the more severe the autistic features, the more the sensory integration dysfunctions. Children with sensory integration dysfunctions are often blamed for their misbehavior. Improving sensory processing in these children can help in improving their social interactions, which would, in turn, help in further developing their sociocommunication skills.

Some auditory processing difficulties have been reported in children with autism. Processing of auditory information at the cortical level was found to be affected in children with autism. However, abnormalities found at the subcortical level were reported to be inconsistent [28].

Some authors believe that an abnormal auditory pathway can act as a major contributing factor to autistic features to the extent that some researchers recommend including auditory abnormalities among the diagnostic criteria of the disorder [29]. Previous studies on auditory perception of linguistic and social auditory stimuli among individuals with autism have revealed impaired perception. Such findings may correlate with impaired language skills and social isolation observed among individuals with autism. However, studies of auditory perception of pitch and music among individuals with autism have shown enhanced perception versus normal controls. These findings may correlate with the restricted, highly focused behaviors observed in autism [30]. These findings suggest impaired global processing and enhanced local processing, which, in turn, could prove useful in understanding the apparent auditory integration dysfunction features that have been reported in autistic children.

On comparing the absolute and interpeak latencies and amplitudes of ABR waves obtained by children with autism with those obtained by controls using a rate of 20 c/s, a statistically significant shift in wave III and interpeak latency (IPL) III–V in addition to a statistically significant shift in wave V and IPL I–V were found (Table 3). On using the system with a high rate (70 c/s), a delay in the Autism group compared with the control group was evident in the latency of wave V′. Hence, it can be concluded that autism mainly affects the latency of the ABR waves and not the amplitude. A slowing in nerve conduction in the auditory system, as expressed by the prolongation of ABR absolute and interpeak latencies, can be deduced. This finding supports the brainstem hypothesis: that there is a dysfunction or immaturity of the lower part of the central auditory nervous system in autism [20].

These findings are consistent with the view that there is electrophysiological evidence of auditory defects in autism

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that may involve lower levels of neural transmission at a very early stage, within several milliseconds after stimulus presentation, as manifested by the abnormalities in the brainstem. The results obtained showed a delay in brainstem propagation, mainly involving the later waves. This delay becomes especially apparent on stressing the system using a high repetition rate. However, it seems that the effect of autism was, generally, on ABR wave latencies and not on amplitudes. There are different explanatory models for the observed combination of ABR abnormalities. One possible explanation is an abnormality in brainstem anatomy. A genetic defect affecting the HOXA 1 gene on chromosome 7 can explain this abnormality. Moreover, hyperserotonemia is the best replicated biochemical abnormality in autistic patients. Serotonine has been found to stop axon elongation for synapse formation of particular neurons [31].

The brainstem and midbrain are early centers in the processing pathway for sensory integration. These brain regions are involved in processes including coordination, attention, arousal, and automatic function, which are part of the sensory integration function [31]. In the present study, a significant positive correlation was found between wave V latency and IPL III–V and auditory dysfunction only on using a low rate of 20 c/s Table 7. According to these findings, it can be suggested that brainstem dysfunction can be a contributing factor to the auditory sensory integration dysfunction present in autism.

This study showed a nonsignificant correlation between ABR latencies and amplitudes and CARS scores in the Autism group Table 4. On the basis of these results, it could be assumed that no deficit specific to the auditory function in autistic children is located at the level of the middle ear or the cochlea. This is in accordance with the emerging evidence that suggests that atypical behaviors in response to sound represent a perceptual disorder mediated at higher not lower levels of the auditory system [32].

The nonsignificant correlation between ABR results, age, and IQ (Table 4) suggests that autistic features, rather than age, or lower mentality, correlated with brainstem transmission time. The autistic characteristics may be related to dysfunction of the brainstem that affects the processing of sensory input through the auditory pathway. The brainstem lesion may be part of a generalized process of neurological damage that accounts for the deviant language, cognitive, and social development in the spectrum of autistic disorder [20].

As ABR does not change with age in autistic children, whereas it changes in normal children, there might be a maturational defect in myelination within the brainstem in autism. This defect may have a wide distribution throughout the central nervous system in autism [20].

There was a significant correlation between the ABR IPL of waves I–III and III–V (nerve conduction time in the brainstem) and verbal and nonverbal communication Table 5. These results imply that brainstem lesions, especially an IPL shift of I–III and III–V, have an impact on communication skills. This is in agreement with other investigators who reported that brainstem lesions may account for the deviant language present in autism [33].

No significant correlation was found between ABR results, IQ, and CARS Table 4. However, a significant negative correlation was found between ABR IPLs and most of the studies on communication skills (Table 5) and a significant positive correlation was found between ABR wave latencies and auditory sensory integration dysfunction (Table 7). This implies that IPL prolongation, as a marker of the neuropathologic process, would not be necessary to develop autism and would not consequently be the sole liability factor for autism. This agrees with the findings previously obtained by other researchers who found that only IPL prolongation is insufficient in the development of autism unless it interacts with other genetic, environmental, and neurological factors [34].

These findings suggest the existence of brainstem abnormalities in children with autism. This is in agreement with the findings previously obtained by other researchers [35], who found significant dysmorphology in the superior olivary complex, a collection of auditory brainstem nuclei, in the autistic brain [35,36].

Conclusion

Some of the communication difficulties exhibited by children with autism might be related to sensory integration dysfunction. Autistic children presented with a normal hearing sensitivity, as evidenced by play audiometry. ABR results showed a delay in brainstem propagation, mainly involving the later waves. This delay was also apparent on stressing the system, using a high repetition rate, indicating a possible impaired synaptic function. Effect of autism is mainly on ABR wave latencies and not on amplitudes. The brainstem dysfunction present in autistic children affects communication and sensory integration functions, and hence affects the process of coordination, attention, and arousal, which are part of the sensory integration function.

Recommendations

Reducing sensory integration deficits can aid in minimizing some of the features commonly encountered in children with autism. This would also help in further development of their sociocommunication skills. ABR, as an objective tool, may be used as a prognostic indicator to monitor the progress achieved by therapy in children with autistic features.

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Conflicts of interest

There are no conflicts of interest.

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Appendix 1. Assessment of communication skills.

	0	1	2	3
I-Signals and their meanings				
1-Shows any significance to certain people	No one	One person	2 persons	More than 2 persons
2-Indicates specific recognition of each of these people	Never	Behavioral	Gestural	Verbal
3-Requests any of these people	Never	Behavioral	Gestural	Verbal
4-Gets severely and inappropriately attached to certain objects	Frequent	Sometimes	Rarely	Never
5-Indicates specific recognition of each of these objects	Never	Behavioral	Gestural	Verbal
6-Has a method of requesting important activities	Never	Behavioral	Gestural	Verbal
7-Can give a yes/no response	Never	Behavioral	Gestural	Verbal
8-Has a method of requesting 'more' and/or 'again'	Never	Behavioral	Gestural	Verbal
9-Indicates that he/she wants an object	Never	Behavioral	Gestural	Verbal
10-Indicates that he/she wants something to stop	Never	Behavioral	Gestural	Verbal
11-Has a way to get others' attention or direct it toward an object?	Never	Behavioral	Gestural	Verbal
II-Forms used to indicate specific requests/needs/emotions				
1-How does the child tell that he/she is hungry/desires food?	Never	Behavioral	Gestural	Verbal
2-How does the child tell that he/she needs to defecate?	Never	Behavioral	Gestural	Verbal
3-How does the child tell that he/she has defecated?	Never	Behavioral	Gestural	Verbal
4-How does the child tell that he/she needs to urinate?	Never	Behavioral	Gestural	Verbal
5-How does the child tell that he/she has urinated?	Never	Behavioral	Gestural	Verbal
6-How does the child tell that he/she is tired?	Never	Behavioral	Gestural	Verbal
7-How does the child tell that he/she is sick?	Never	Behavioral	Gestural	Verbal
8-How does the child tell that he/she is cold?	Never	Behavioral	Gestural	Verbal
9-How does the child tell that he/she is hot?	Never	Behavioral	Gestural	Verbal
10-How does the child tell that he/she is uncomfortable (position)?	Never	Behavioral	Gestural	Verbal
11-How does the child tell that he/she is in pain?	Never	Behavioral	Gestural	Verbal
12-How does the child tell that he/she is itchy?	Never	Behavioral	Gestural	Verbal
13-How does the child tell that he/she desires physical contact?	Never	Behavioral	Gestural	Verbal
14-How does the child tell that he/she is happy?	Never	Behavioral	Gestural	Verbal
15-How does the child tell that he/she is sad?	Never	Behavioral	Gestural	Verbal
16-How does the child tell that he/she wants/doesn't want to interact with others?	Never	Behavioral	Gestural	Verbal
17-How does the child tell that he/she is angry?	Never	Behavioral	Gestural	Verbal
18-How does the child tell that he/she is surprised?	Never	Behavioral	Gestural	Verbal
19-How does the child tell that he/she is greeting you/others?	Never	Behavioral	Gestural	Verbal
20-How does the child tell that he/she is seeking permission?	Never	Behavioral	Gestural	Verbal
III-Behavior				
The child's positive behaviors that are socially acceptable	Never	Behavioral	Gestures/ expressions	Verbal and sounds
The child's negative behaviors that are socially unacceptable	Frequent/ physical	Sometimes verbal/ behavior	Occasional behavioral	Never
IV-Intentionality (to what extent the child uses his signals to intentionally indicate his needs)				
1-Alternates his/her gaze between a goal and a person	Never	Sometimes	Frequent	Always
2-Persists in signaling until his/her goal is achieved	Never	Sometimes	Frequent	Always
3-Changes the quality of the signal until the goal is achieved	Never	Sometimes	Frequent	Always
4-Makes a signal more conventional when needed?	Never	Sometimes	Frequent	Always
5-Waits for a response from others	Never	Sometimes	Frequent	Always
6-When a goal is met, does the child stop his/her signal?	Never	Sometimes	Frequent	Always
V-Readability of communication behaviors				
1-Description of the child's communication behaviors in terms of three criteria: movement clarity, adequate frequency (not rare and not unnecessarily routinely repetitive), and consistency	Unclear	Fulfilling one criteria	Fulfilling two criteria	Fulfilling 3 criteria
2-How conventional or easily understood are the child's signal to others?	Not understood	Understood after two repetitions	Understood after one repetition	Easily understood without repetitions
3-How quickly does the child react to other's misunderstandings and initiate a repair effort?	Never	Repeat same signal once	Repeat same signal many times	Use others means of communication
VI-Capacity of symbols				
1-Verbal: Does the child understand and follow verbal instructions? (instructions graded in length and number of constituent orders were introduced to test this area)	Never	Understands and follows simple instructions	Understands and follows two-sequential instructions	Understands and follows three sequential instructions

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2-Nonverbal: Does the child understand pictures? Sets of three pictures were introduced. For each set, the child was asked to a certain picture named by the assessor	Never	Identify one picture	Identify two pictures	Identify three pictures
3-Does the child understand conventional signs?	Never	Sometimes	Frequent	Always
4-Does the child understands printed words?	Never	Sometimes	Frequent	Always
VII-Imitation				
1-Does he/she imitate others' vocalizations, words, or sentences?	Never	Vocally imitate sounds	Vocally imitate words	Vocally imitate phrases
2-Does he/she imitate others' motor actions?	Never	Imitate simple body movements	Imitates motor actions involving one object and using one action	Imitates motor actions involving more than one object and/or more than one action
VIII-Reasoning				
1-Does he/she use an object in a way that shows that he/she understands their function (puts a hat on head, take an empty spoon to mouth).	Never	Sometimes	Frequently	Always
2-Does he/she use an object like a tool to solve problems, e.g. uses a chair to reach a high object out of reach, etc.?	Never	Sometimes	Frequently	Always

Appendix 2. Sensory Integration Dysfunction questionnaire.

0 = Never 1 = Sometimes 2 = Frequently

Auditory system
- 1-Negatively responds to unexpected noises
- 2-Has difficulty paying attention when there are other noises nearby
- 3-Seems confused as to the direction of sounds
- 4-Needs directions repeated
- 5-Becomes unable to function if 2 steps of instructions are given
- 6-Seems to enjoy strange noises and/or makes loud noises
- 7-Appears to be hard of hearing
- 8-Shows sudden outburst of self-abuse or withdrawal in response to auditory stimuli

Visual system
- 1-Has difficulty keeping eyes on object
- 2-Tilts head/close one eye to look at an object
- 3-Has difficulty in building blocks
- 4-Is hesitant in going up or down steps
- 6-Has difficulty in finding his way from one place to another
- 7-Dislikes to be in strange places
- 8-Appears to be happier in dark
- 9-Picks up pictures/objects and looks closely and carefully at them

Olfactory–gustatory system
- 1-Acts as though all food tastes the same
- 2-Mouths/chews on nonfood objects
- 3-Has unusual cravings for certain foods
- 4-Dislikes foods of certain textures
- 5-Makes excessive use of smell to explore
- 6-Does not discriminate odors
- 7-Negatively reacts to smell
- 8-Ignores unpleasant odors

Vestibular system
- 1-Jumps a lot
- 2-Spins and whirls more than others
- 3-Seems fearful of space, e.g. going through small enclosed areas
- 4-Gets car sick or dizzy easily
- 5-Avoids jumping down from a higher surface to a lower one
- 6-Is particularly slow at some movements, e.g. getting in to a car or sitting down on the floor
- 7-Is afraid of walking on a raised surface
- 8-Has difficulty in judging space accurately

Tactile system
- 1-Avoids being touched on the face
- 2-Dislikes having hair cut or washed
- 3-Dislikes having a bath
- 4-Is sensitive to certain fabrics and avoids wearing clothes made of them/dislike turtle neck shirts
- 5-Has unusual need for touching, please specify
- 6-Tends to feel pain less than others
- 7-Tends to feel pain more than others
- 8-Dislikes being touched even in a friendly and affectionate way

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