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Evaluation and remediation of central auditory processing disorders in children with autism spectrum disorders

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ABSTRACT

Objectives: This study was carried out to assess various skills of central auditory processing (CAP) in children with autism spectrum disorders (ASD) and to evaluate the efficacy of auditory training in these children.
Methods: This study is a non-randomized clinical experiment. 30 high functioning ASD children aged from 7 to 12 years were included in the study. They underwent behavioral assessments of CAP skills with subsequent remediation by dichotic training therapy for the children who revealed dichotic deficits.
Results: Scores of CAP skills in ASD children are wide-ranging from completely normal to substantially defective and generally lower than those of typically developing children. By auditory training, ASD children improved their dichotic deficits as well as other untrained areas of auditory and language processing skills.
Conclusions: A group of ASD children showed different degrees of abnormalities in CAP that could be measured behaviorally and achieved benefits from auditory training in improving their dichotic listening, auditory and language processing skills.

1. Introduction

Autism spectrum disorder (ASD) is a heterogonous behaviorally labeled disorder that is characterized by limitations in social contact and communication skills and associated with repetitive patterns of behaviors and interests and atypical sensory processing [1]. Sensory processing difficulties in ASD individual are numerous affecting almost all senses including the auditory domain [2]. These perceptual disruptions are considered an essential diagnostic finding in ASD [1] and constitute the building blocks for higher order functions specially speech and communication [3]. Abnormal auditory processing is considered one of the main reasons of language weakness in ASD [4,5].

There are evidences for reduced orientation to auditory information and in particular to speech in ASD [6], impaired processing of speech in background noise [7], impaired processing of affective prosody, and grammatical prosody has also been observed in ASD [8–11]. Structural and functional abnormalities that contribute to auditory processing impairments were evident in individuals with ASD [12]. Corpus callosum (CC); a brain structure that is directly involved in inter-hemispheric transfer of auditory information was found to be of small size or even agenetic in ASD [13–15]. Deficits in dichotic listening had been proved to be related to language and learning in children [16]. While performing dichotic listening tasks, some ASD children do not show the usual right ear advantage for speech stimuli [17], instead they prefer to use their left ear when listening to both speech and musical stimuli [18]. Studies of handedness indicated presence of high rates of left handedness in ASD [19,20].

The human brain has the ability to change and to reorganize in response to environmental modifications, which is known as plasticity [21]. Auditory training has been shown to produce long-lasting functional and structural changes in the brain and modify the aberrant connections in ASD, with subsequent enhancement of auditory processing in ASD [22–24].

Unfortunately, there is limited behavioral research on measuring auditory processing skills in ASD children and evaluation of auditory training in these children. Dichotic training had improved dichotic listening and reduced interaural asymmetry in children diagnosed with speech and language disorders, head trauma, and also had improved language processing in typically developing children [25–27].

ASD is not labeled by cognitive impairment, so we hypothesized to measure auditory processing skills in ASD children behaviorally and then to target dichotic listening deficits by dichotic training and we predicted that children with ASD may benefit from such training by reorganizing and strengthening the neural substrates involved in

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dichotic listening with subsequent improvement of other auditory and language processing skills.

2. Methods

2.1. Subjects

A total number of 30 children with a diagnosis of ASD according to Diagnostic and Statistical Manual of Mental Disorders (DSM-5) specifications [1] among those who attended outpatient neuropsychiatry clinic of Alexandria University Children Hospital were included in this study. They ranged in age from 7 to 12 years. There were five females and 25 males in the study. All of them had Intelligence Quotient (IQ) levels above 70, were verbal with a language age of at least six years, with normal peripheral hearing measured by pure tone audiometry and word recognition thresholds and free from neurological and genetic disorders. The study was approved by the Ethics Committee of Alexandria Faculty of Medicine (IRB NO: 00007555) based on The Belmont Report and Declaration of Helsinki 1964 and its later amendments. Informed consents were taken from the parents after detailed explanation of the study and the privacy rights of our participating children were observed throughout the study.

2.2. Pre-training measurements

2.2.1. History taking and examination

Detailed history was taken from parents that included perinatal and natal history, developmental milestones, medical history and language development. Parents also reported about their children listening problems and academic performance, they also reported about their children handedness. All participating children were subjected to comprehensive neurological and otological examinations.

2.2.2. Audiological measurements

Assessment of peripheral hearing was done by measuring pure tone air and bone conduction thresholds along the frequency range (250–8000 Hz) and Speech Audiometry by measuring speech recognition threshold (SRT) with the ASHA-recommended, Bracketing techniques, to find the lowest level that the children could repeat the spondaic words back at least 50% of the time [28]. Middle ear function was assessed by tympanometry and measuring the acoustic reflex thresholds.

2.2.3. Dichotic listening measurements

Dichotic listening abilities were measured by the Arabic version of dichotic digit test (DDT) [29], a test that assesses the process of binaural integration where two digits were presented to the right ear and two differing digits were presented to the left ear requiring the child to repeat all four digits, the percentage of correct responses were calculated for each child for right and left ears, the more advantageous ear was called strong ear (SE) while the less advantageous ear was called the weak ear (WE). Ear advantage (EA) was calculated by subtracting Left ear scores from those of Right ear and was considered as an indicator for interaural difference between both ears. The scores of ASD children were compared to the normative scores of 30 typically developing (TD) children matched for age and sex among those who attended the audiology clinic at Alexandria main university hospital. The control group ranged in age from 7 to 12 years and comprised also 25 boys and 5 girls, all of them had normal hearing levels. CAPD was indicated by deteriorated overall responses, or the presence of a larger right ear advantage and a significantly poorer left ear score than normative values, or a reversal of ear advantage and more advantageous left ear.

2.2.4. Behavioral auditory and language processing measurements

Auditory processing skills were measured by using an Arabic version [30] of three subtests of SCAN3-C [31] test, a test that was designed to identify deficits in CAP skill areas in children. These subtests were auditory figure ground subtest (AFG), competing word subtest (CW), filtered words subtest (FW). In AFG subtest, monosyllabic words were recorded in the presence of multi-talker speech babble noise at +8 dB signal-to-noise ratio (SNR) and the children were asked to repeat the stimulus words in the presence of this background noise, two practice words and 20 test words were presented to the right ear and then two practice and 20 test words were presented to the left ear. For CW subtest, monosyllabic word pairs that were digitally compressed to achieve equal duration presented to the right and left ears simultaneously requiring the children to repeat both words, first, two practice word pairs and 30 test word pairs were presented, as for DDT; we used the term SE for the more advantageous ear and WE for the less advantageous one to express the dominance in dichotic tasks. As regard FW subtest, the testing materials were monosyllabic words that were low-pass filtered at 1000 Hz with a roll-off of 32 dB per octave, two practice and 20 test words were presented to the right ear, then two practice words and 20 test words were presented to the left ear. The percentage of correct responses for each of right and left ears on each subtest were calculated for each child.

Phonological processing skills were also assessed for our participating children by using a test for phonological awareness [32] This test included 13 items namely; Rhyme Recognition, Rhyme Production, Syllable Segmentation, Syllable Blending, Final Phoneme Identification, Initial Phoneme Identification, Middle Phoneme Identification, Phoneme Blending, Phoneme Segmentation, Initial Phoneme Deletion, Middle Phoneme Deletion And Phoneme Substitution. Each item had a score ranged from zero to ten and the scores were calculated by counting the number of correct response in each test item. The results of these auditory processing and language processing skills were then compared to the 30 TD children.

2.3. Instrumentation and testing environment

All measures were performed in a sound treated room. Children were examined individually with each child seated comfortably at a small table and were positively reinforced to participate in testing. Materials for testing were recorded on a CD player and routed to a clinical audiometer (Otometrics MADSEN Astera). The recorded stimuli were delivered through TDH49 supra aural earphones. The volume setting was set at level of 48–50 dB SL re SRT.

2.4. Remediation of dichotic deficits

Those children who showed significant interaural asymmetry due to poorer performance in the non-hemispheric dominant ear (WE) on DDT were subjected to further auditory remediation "a significant interaural asymmetry was defined as a difference of greater than 20% for children younger than age eight years, 15% for children ages eight to nine years and greater than 10% for children ages ten years and older" [25]. Thirteen children met these preset criteria for remediation and an additional child "S1" (Table 1) was included in the training, he was seven years old with EA of 16 on DDT, however CW subtest showed a difference of 24% between both ears (Table 2) and he was exceptionally added based on that criterion, so we had a total number of 14 children who underwent for auditory training. Permissions to participate in training were obtained from the parents. The remediation was based on dichotic interaural intensity difference (DIID) training. The protocol of training was adapted from constraint induced auditory training (CIAT) program (Hurley & Davis, 2011) [33].

The training was conducted in the same testing environment using dichotic digits as a training material. Training consisted of 30-min sessions that were planned to be two times per week for six weeks to be likely effective. We started with the signal presented to WE remained constant at 55 dB Hl and that presented to SE was decreased and the