

Auditory Hypersensitivity in Autism Spectrum Disorder: Assessment, Challenges, and Therapeutic Approaches

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Abstract:

In recent years, our understanding of autism spectrum disorders (ASD) has evolved, allowing us to better understand and treat those affected by it. ASD affects behavior, physical aspects, and social development in millions of individuals nationwide. Among ASD the challenges faced by individuals with ASD, hyperacusis (reduced sound tolerance) is commonly found. This paper examines ASD's link to auditory sensitivity, especially hyperacusis, covering symptoms, causes, and interventions. Interventions such as cognitive behavioral therapy (CBT) and desensitization methods show promising results in alleviating symptoms of those with ASD. In conclusion, tailored approaches are needed for complex ASD challenges and treatment varies by individual. In order to better treat ASD, more research must be done to better understand the etiology and intricacies of this disorder. This paper emphasizes the significance of understanding ASD nuances and auditory aspects, promoting research for enhanced autism spectrum lives.

1. Introduction

The advancement of medical research has led to many discoveries related to medical disorders. Over the past century, new findings have challenged previously held notions about neurological disorders. Our understanding of autism spectrum disorders (ASD) and related conditions has grown significantly. ASD are a spectrum of neurological developmental disorders characterized by a series of behavioral, psychological, and physical conditions. This can include delays in social development, repetitive behaviors, and sensory disorders. Hyperacusis, also known as decreased sound tolerance (DST), is one of the most common disorders that ASD patients face.¹

As our knowledge of ASD and DST expands, so too does our understanding of diagnoses and treatments. ASD describes a wide spectrum of disorders filled with nuance and individuality. Thus, when pursuing diagnosis and treatment, it is critical that experts fully understand the differences that lie among different presentations of ASD. To address the challenges faced by individuals with ASD, it is important to first understand the background pertaining to aural perception and hyperacusis of ASD.

2 Autism Overview and Symptoms

2.1 Overview of ASD

Autism Spectrum Disorders are a series of neurological disorders that affect social behaviors.¹ ASD is a common disorder diagnosed in roughly one in every thirty-six American children according to the Centers for Disease Control and Prevention (CDC).² Currently, over 5.4 million adults in the United States have ASD or a disorder that falls under ASD.³ Although there are many treatments available for patients with ASD such as behavioral therapy, cognitive therapy, and educational therapies, among others, there are currently no cures.

¹ Lord et al., "Autism Spectrum Disorder."

²"Signs & Symptoms | Autism Spectrum Disorder (ASD) | NCBDDD | CDC."

³ "CDC Releases First Estimates of the Number of Adults Living with ASD."

2.2 Symptoms of ASD

ASD can be characterized in adolescents by challenges in certain behaviors such as communication, socialization, and sensory sensitivity.⁴ The Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5). In recent years, disorders such as Kanner's Syndrome and Asperger's Syndrome have been integrated into the broader spectrum of ASD. This has expanded the variety of symptoms and behaviors in patients with these disorders by grouping symptoms from different disorders together under the term of ASD. Patients diagnosed with ASD frequently have symptoms that present differently. The complex and individualistic nature of ASD makes diagnosis hard as it can overlap with other neurological disorders. Patients frequently will receive a diagnosis for other neurological disorders in addition to being diagnosed with ASD. The most recent criteria for ASD diagnosis as listed by the DSM-5 outlines key characteristics of ASD that lead to diagnosis.⁵ The DSM-5 categorizes observable deficits in socialization as symptoms of ASD that include "adjusting behavior in various social contexts, difficulties in sharing imaginative play or in making friends, or lack of interest in peers".⁵ Another criteria for ASD diagnosis includes "poorly integrated verbal and nonverbal communication, and eye contact and gesture/body language abnormalities." (DSM 5). Lastly, the manual also describes "Hyper- or hypo-reactivity to sensory input" as a criterion for an ASD diagnosis. This includes lowered tolerance to aural stimuli.

2.3 Causes of ASD

Recent studies that employ modern techniques such as brain imaging provide a deeper understanding of the possible causes of ASD. Studies have asserted that aberrations in certain structures in the brain's limbic system⁶ and cerebral cortex⁷ are linked to the presence of ASD.⁵ In 1996, Bachevalier demonstrated the effects of experimental damage to the amygdalohippocampal complex of infant monkeys and related it to behaviors found in children with ASD⁶. A neuroimaging study done by Zilbovicius compared the metabolic and development of the prefrontal cortex in young children with ASD to those of neurotypical age-matched subjects.⁷ The results concluded that the subjects with ASD presented lower levels of blood flow to the prefrontal cortex compared to their neurotypical age-corresponding subjects until the ages of 6 or 7.⁷

3. Overview of Auditory Processing and Hearing Related Disorders

3.1 The Process of Auditory Processing

The process of human aural perception is an elaborate procedure that undergoes many steps. First, sound waves travel from their origin into the pinna located in the outer ear. This elaborate structure consisting of folded cartilage and bone allows the sound waves to be funneled directly into the ear canal. As the sound waves travel into the middle ear, they reach the eardrum. The eardrum receives these sound waves and vibrates the eardrum where they are then sent to the three-ossicle bone structure, which is also located in the middle ear. This structure consists of the hammer (malleus), anvil (incus), and stirrup (stapes). The malleus is attached to the

⁴ "CDC Newsroom."

⁵ Hodges, Fealko, and Soares, "Autism Spectrum Disorder."

⁶ "Bachevalier, J. Brief Report: Medial Temporal Lobe and Autism: A Putative Animal Model in Primates. *J Autism Dev Disord* 26, 217–220 (1996). <https://doi.org/10.1007/BF02172015>"

⁷ Zilbovicius et al., "Delayed Maturation of the Frontal Cortex in Childhood Autism."

eardrum, vibrating the eardrum as it receives external sound waves. The malleus connects to the incus through the incudostapedial joint which allows it to transmit vibrations to the incus. The incus then transmits vibrations to the stapes which transmits the vibrations from the sound waves into the oval window. The oval window is the membrane-covered opening of the fluid-filled cochlea which is located in the inner ear. The inner ear is made up of semicircular canals, the vestibule, and the cochlea. These organs control balance, equilibrium, and auditory perception, respectively. As the oval window receives sound waves, the fluid inside the inner ear gets converted into electrical signals when the hair cells in the cochlea bend. The auditory nerve receives the electrical signals. At this point, the electrical signals can take two pathways to reach the brain: a direct and an indirect pathway.

3.2 Overview of Auditory Pathways

The first way these electrical impulses travel to the brain is through the direct pathway. This pathway is the primary route that auditory electrical signals travel through. First, electrical signals from the auditory nerve travel to the brainstem. Then, this electrical impulse continues through the auditory path to the thalamus and then finally the auditory cortex which is located in the temporal lobe.

In addition to the direct auditory pathway, humans can also process sound through the indirect auditory pathway. This process is similar but diverges from the direct pathway after the auditory nerve. After reaching the auditory nerve, the indirect auditory pathway can take two different routes in addition to the direct auditory pathway. One of these includes a pathway where electrical impulses move through the Superior Olivary Complex (SOC). The SOC is a section of the brainstem that helps process sound intensity and localization. After the signals reach the SOC, they are then transferred to the inferior colliculus which is located in the midbrain. This structure integrates and helps analyze the information generated from the external sound

Another indirect auditory pathway relays the electrical signals into the Medial Geniculate Body (MGB). The MGB is located in the thalamus where sound is also processed through the direct pathway. After this, the signals move from the MGB into the auditory cortex in the temporal lobe of the brain. The auditory cortex functions to process language, speech, and sound in general. This area includes parts of the brain such as Wernicke's area, which is responsible for speech motor functions and articulation.

The complexities of the auditory system are often best understood when fundamental aspects of our ability to hear are disrupted. This is perhaps best illustrated in conditions such as hearing loss, deafness, and complex neurological and psychiatric conditions such as Autism Spectrum Disorders.

3.3 Hyperacusis and Decreased Sound Tolerance

Decreased sound tolerance (DST) is a neurological disorder that affects the auditory system. DST affects auditory perception and can manifest in diagnoses such as misophonia or hyperacusis. Hyperacusis describes a condition in which a person's sound tolerance is relatively low. Those diagnosed with hyperacusis experience discomfort when exposed to sounds that are of low to moderate intensity. Everyday sounds, such as hand dryers or alarms, may be harmless to the average person; however, audio-sensitive individuals find these sounds to be psychologically or physically distressing. Case studies, empirical data, and research done by clinicians work to thoroughly understand the experiences of those with ASD and hypersensitivity

to sound. Individuals with this disorder have heightened sensitivity and perception of sensory stimuli in general.

3.4 Exploring Auditory Capacity: A study by Remington and Fairnie

In 2017, a study conducted by Remington and Fairnie implemented two behavioral tests in adolescents and adults with ASD to assess their auditory capacity. The study applied a series of auditory detection and identification assessments to determine each person's auditory strengths and weaknesses. The study found that individuals with ASD performed better than neurotypical individuals on tasks that required detecting different and unexpected sounds. The series of tests pointed to the prospect of ASD-affected individuals possessing a larger auditory and sensory capacity. Rather than having diminished sensory filtration capabilities, autistic individuals exhibit a greater capacity for perceiving sensory stimuli. This increased capacity is ultimately what leads to the distress caused by sensory overload.

3.5 Challenges Associated with Hyperacusis and ASD

ASD and audio sensitivity can induce significant stress in patients' daily lives. Sounds not perceived as benign by neurotypical individuals may be highly bothersome to the ASD community. Sounds generated by machines, such as cars, alarms, TVs, and radios, may irritate those with ASD. Unfortunately, these stimuli are ever-present and almost unavoidable in some environments and situations. As ASD and hyperacusis are complex neurological disorders, it is important to note the variability found in symptoms among patients. Sounds that are higher in amplitude or frequencies are generally less tolerable by individuals with ASD. However, the heterogeneous nature of this disorder reflects that individuals have different tolerances to different frequencies and intensities of auditory stimuli. Given the hyperacusis uncomfortable loudness level (ULL) minimum established by Dr. Haashir Aazh, many everyday sounds such as car horns, alarm clocks, and lawnmowers far surpass the 77 dB threshold. These are a few of many examples of auditory stimuli that induce significant physical and psychological distress in those with ASD.

These effects may manifest in emotional disturbances and distress. Presentations of this include behaviors such as covering one's ears and avoiding public environments. More extreme examples include running away, crying, and emotional outbursts. Reactions like these detriment an individual's ability to participate in daily activities and can adversely impact one's performance in school, the workplace, and social life. A qualitative study conducted by Sara Ryan collected anecdotal reports from parents of children with ASD to highlight different accounts of emotional outbursts. One example in the report described a mother's experience with her child who has ASD:

"If anybody turned the hand drier on he went berserk because the noise must have hurt his ears, but you just don't know what's the matter. You are distressed because they are distressed. (Jane, son aged 13)."

Other symptoms experienced by those with hearing sensitivity include distressing physical sensations. The previously mentioned experiences patients have can be manifestations of physical discomfort. A retrospective case note evaluation produced by Myne and Kennedy reported that 8% of the audio-sensitive children in the study dataset reported pain in the head and ears.

3.6 Causes of Hyperacusis

Factors that may contribute to the presence of DST in individuals have been proposed, however, the complex nature of neurological disorders causes each case to be unique. Different severities of ASD may correlate with variable discrepancies in brain structure and often diagnosis cannot be traced back to a single etiology. One proposed theory is superior semicircular canal dehiscence (SSCD), which refers to a thinning or absence of the bone covering the superior semicircular canal. This theory was proposed in a study conducted by Thabet and Zahgoul where CT images of children with ASD and DST were evaluated to determine biological correlates. 4 of the 14 children in the study (29%) had SSCD.⁸ One of these participants had SSCD bilaterally, while the other three had SSCD unilaterally.⁸ Thabet conducted a subsequent study involving 14 children with both hyperacusis and ASD and 15 age and gender-matched ASD-affected children without hyperacusis, served as the control group.⁹ In this study, they used vestibular evoked myogenic potential (VEMP) to determine whether the audio sensitivity is caused by superior canal dehiscence or by dehiscence caused by bone immaturity associated with ASD.⁹ In addition, a review published in *Otology and Neurotology* by Katzenell and colleagues proposed aberrations in cochlear structures as a cause for hyperacusis.¹⁰

Furthermore, several brain functions beyond the auditory system may be responsible for the development of hyperacusis. Some studies suggest that hyperacusis may be a symptom of 5-hydroxytryptamine (5-HT) dysfunction.¹¹ This disturbance in 5-HT, or serotonin, is commonly found in neurological disorders associated with hyperacusis such as autism spectrum disorder.¹² Additionally, certain theories propose that hyperacusis stems from decreased inhibition in the cochlear nucleus. This induces a rearrangement in the tonotopic map of the dorsal cochlear nucleus.¹³ This causes inferior colliculus neurons to respond to auditory stimuli with a greater amplitude of auditory evoked potentials. This has also been linked to a decrease in GABAergic inhibition on inter-layer collision neurons.²⁰

4. Assessment of Hearing Sensitivity in ASD

Due to the complex nature of ASD, patients with this disorder have varying degrees of sound tolerance. Therefore, assessing auditory sensitivity in individuals with ASD is crucial to pursuing treatment and accommodating their needs. The varying extremities of hyperacusis in ASD patients are the outcome of a variety of intricate physical and social factors. In order to assess this, specialists have implemented many different tools to assess the severity of audio sensitivity among different patients.

Hyperacusis can be diagnosed using a variety of different methods. One method used to diagnose this disorder is pure tone audiometry (PTA). This method is used to test the weakest sounds patients can perceive at different frequencies (0.5, 1, 2, and 4 kHz).¹⁴ Conversely, clinicians also use uncomfortable loudness level (ULL) tests to determine a measure of the

⁸ Thabet and Zaghoul, "Auditory Profile and High Resolution CT Scan in Autism Spectrum Disorders Children with Auditory Hypersensitivity."

⁹ Thabet, "Ocular Vestibular Evoked Myogenic Potentials N10 Response in Autism Spectrum Disorders Children with Auditory Hypersensitivity."

¹⁰ Katzenell and Segal, "Hyperacusis."

¹¹ Marriage and Barnes, "Is Central Hyperacusis a Symptom of 5-Hydroxytryptamine (5-HT) Dysfunction?"

¹² Chugani, "Role of Altered Brain Serotonin Mechanisms in Autism."

¹³ Szczepaniak and Møller, "Effects of (-)-Baclofen, Clonazepam, and Diazepam on Tone Exposure-Induced Hyperexcitability of the Inferior Colliculus in the Rat."

¹⁴ Aazh et al., "Insights from the Third International Conference on Hyperacusis."

sound levels along different frequencies (0.25, 0.5, 1, 2, 3, 4, 6, and 8 kHz) which are found to be uncomfortably loud by patients.²¹ On average, neurotypical patients without hyperacusis reported their maximum threshold for the ULL test to be 100 dB.^{21,15} Based on outcomes collected in a study done by Aazh and Moore¹², participants with hyperacusis reported that the trans-frequency average for maximum dB tolerance was 77dB. This was established as the mark of indication for hyperacusis and anything that met or fell below this value would indicate the presence of hyperacusis.¹² However, other studies suggest that ULL indication ranges from 60-85 dB.^{21,16} This may be largely due to the fact that the perception and interpretation of auditory stimuli vary greatly among patients that have hyperacusis and other underlying physical and psychological factors that may impact their threshold reporting.

In addition to PTA and ULL testing, specialists commonly use other empirical and observational methods to identify patients with hyperacusis. This includes assessments such as case history interpretations, self-reporting questionnaires, and clinical observations. Practitioners often use an assessment known as the hyperacusis questionnaire (HQ) to empirically ascertain the presence of hyperacusis in patients by determining the auditory stimuli impacting their anxiety, concentration, mood, physical tolerance, and emotional tolerance.¹⁷ 95% of patients diagnosed hyperacusis in accordance with the 77 dB ULL threshold obtained by Aazh and Moore¹² also met the score minimum (22 points) set by the criteria of the HQ.

5. Auditory Hypersensitivity in Individuals with ASD

Figures estimating the prevalence of audio sensitivity in the ASD population vary greatly. Based on results obtained in a pilot study conducted in 1995, up to 40% of the ASD population had some form of an auditory disorder.¹⁸ Another study conducted by Danesh and colleagues estimated that 69% of participants with ASD indicated the presence of hyperacusis.¹⁹

This study implemented criteria such as the hyperacusis questionnaire, case study evaluation, and the tinnitus handicap inventory.²⁶ A study conducted in 2019 by Hussein and associates used questionnaires given to parents of ASD patients and received responses that indicated 86% of the participants had observed auditory sensitivity in their children.²⁰

Inversely, certain clinicians and scientific literature suggest that the presence of auditory sensitivity points to the presence of ASD in an individual.^{9,21} Although conclusive diagnoses and evaluations of ASD and hyperacusis may be difficult to achieve, comprehensive literary evaluation points to the co-occurrence of DST and other hearing-related disorders in those with ASD.

6. Therapeutic Approaches for Hearing Sensitivity in Individuals with ASD

ASD is a complex neurological disorder for which there is currently is no cure. The unique experiences of those with ASD cause therapeutic intervention to be complicated. However,

¹⁵ Jastreboff and Jastreboff, "Decreased Sound Tolerance."

¹⁶ Jastreboff and Jastreboff, "Treatments for Decreased Sound Tolerance (Hyperacusis and Misophonia)."

¹⁷ Aazh et al., "Psychometric Evaluation of the Hyperacusis Impact Questionnaire (HIQ) and Sound Sensitivity Symptoms Questionnaire (SSSQ) Using a Clinical Population of Adult Patients with Tinnitus Alone or Combined with Hyperacusis."

¹⁸ Rimland and Edelson, "Brief Report."

¹⁹ Danesh et al., "Tinnitus and Hyperacusis in Autism Spectrum Disorders with Emphasis on High Functioning Individuals Diagnosed with Asperger's Syndrome."

²⁰ Hussein, "Family Experiences of Auditory Hypersensitivity in ASD."

²¹ Bonnel et al., "Enhanced Pitch Sensitivity in Individuals with Autism."

there are numerous strategies employed to accommodate the needs of individuals with ASD and auditory sensitivity

6.1 Noise Canceling Devices

One approach that is commonly used, especially among those with more severe audio sensitivity, is the use of noise-canceling devices. A number of specialists would advise individuals with ASD to wear noise-canceling headphones, earbuds, or earplugs in public environments. While well-intended, these methods often augment the sensitivity of the auditory system which further exacerbates hyperacusis.^{22,23} This method exacerbates hyperacusis because the prolonged reduction of auditory stimuli can lead to a heightened perception of the remaining sounds, fostering selective attention to quieter or distant sounds.

6.2 Desensitization

In contrast, desensitization is a therapeutic approach that involves exposing patients to auditory stimuli. This approach has been widely used for several years, involving a variety of different methods and types of sound. Various auditory stimuli are used, including briefly exposing patients to sounds with a broad range of sound amplitudes.^{29,24} A retrospective analysis conducted by Jastreboff looked at desensitization therapies administered to 4,000 patients. The patients were diagnosed with tinnitus and/or hyperacusis and were split into four categories based on their diagnosis. The treatment regimen involved customized care that involved sound generators, hearing aids with a stress on the auditory stimulus, sound generators set above the threshold of hearing, sound generators set at the threshold, a very slow increase of sound level, and some cases also involved counseling. The patients underwent treatment for 18 months, and their progress was evaluated twice during the period between 3 months to 3 years after completing the treatment. The patients were assessed using Jastreboff's improvement criteria which implicated: (1) A previously interfered activity is no longer affected; (2) tinnitus awareness, the impact of tinnitus on life, and tinnitus annoyance decreased by at least 20 percent; (3) and patients were evaluated at least twice after at least 6 months of treatment and before 3 years after treatment; (4) an improvement in more than one category.

6.3 Pink Noise Therapy

Additionally, certain studies have proposed desensitization methods such as pink noise therapy. Pink noise, also known as 1/f noise or fractal noise, describes a type of sound with a frequency spectrum that such that the energy intensity of a frequency is inversely proportional to the frequency of its signal. This means that higher frequencies will carry less energy while lower pitches sounds will have carry more energy. Sounds that resemble pink noise include sounds with a balanced tone such as waves crashing or steady rain. This procedure Vernon and Press proposed a procedure that advised patients to wear headphones and listen to pink noise set at the highest comfortable volume for two hours every day. Out of the 13 patients who reported

²² Vernon, J, *Treatment for Hyperacusis*.

²³ Formby, Sherlock, and Gold, "Adaptive Plasticity of Loudness Induced by Chronic Attenuation and Enhancement of the Acoustic Background."

²⁴ Jastreboff and Jastreboff, "Tinnitus Retraining Therapy (TRT) as a Method for Treatment of Tinnitus and Hyperacusis Patients."

using pink noise therapy methodically, 7 (54%) of the patients reported improvement in their DST.²⁹

6.4 Auditory Integration Training

A more widely known treatment, known as Auditory Integration Training (AIT), has been prevalent for a number of years, however, its efficacy is disputed. This form of intervention begins by determining whether a patient has “uneven hearing” or “hypersensitive hearing” using audiometric assessments. Following this assessment, patients would then receive treatment that consists of twenty 30-minute sessions of individualized sessions. These sessions consist of exposing patients to audio frequencies that are deemed to be susceptible by measuring beaks in the audiogram.¹ Changes in the audiogram and patient behavior indicate progress and the audio frequencies are changed as the patient progresses. Although certain scientific literature points to the prospect of this AIT, there are yet to be randomized control studies that support its efficacy.¹ A meta-analysis authored by Sinha and associates²⁵ concluded that the literature surrounding AIT could not prove that AIT was an effective form of intervention. This was due to the heterogeneity of the data presented by the different studies.

6.5 Cognitive Behavioral Therapy

Additionally, cognitive behavioral therapy (CBT) has been implemented to treat hyperacusis.^{21,29,26} Aazh and Moore engaged in collaborative work with psychologists and auditory specialists to assess the effectiveness of CBT in DST-affected individuals.²⁷ It was reported that of the 75 patients who participated in the study, 56% graded the effectiveness of CBT as a 5/5 (where 5 means highly effective) while 29% graded CBT as a 4/5. There has not been scientific literature published regarding the application of CBT on individuals with ASD with DST. However, studies have highlighted the efficacy of CBT in adolescent autistic individuals experiencing concomitant anxiety. One randomized control trial involved 31 subjects aged 11-16 who were diagnosed with ASD and clinical anxiety. 16 participants underwent 16 weeks of personalized CBT while the other 15 underwent treatment as usual (TAU). The participants who underwent CBT developed coping capabilities and exposure therapy. The participants were evaluated by blinded raters at the initial screening, post-treatment, and one month after post-treatment.²⁸ The results from this study concluded that 11 out of the 16 CBT patients improved while 4 of the 15 TAU patients improved.³⁴ These data point to the promising outcomes regarding the implementation of CBT in individuals with ASD.

6.6 Surgical Interventions for Vestibular Disturbances

Other treatments may serve to alleviate symptoms of audio sensitive individuals. In rare cases, individuals with severe DST can encounter vestibular disturbances (loss of balance, motion sickness, nausea, vertigo) when exposed to ordinary sounds. This condition, called Tullio Phenomenon or vestibular hyperacusis, is caused by superior canal dehiscence syndrome. This can be treated by certain surgeries that address the aberrations found in the auditory system's

²⁵ Sinha et al., “Auditory Integration Training and Other Sound Therapies for Autism Spectrum Disorders.”s

²⁶ Hiller and Haerkötter, “Does Sound Stimulation Have Additive Effects on Cognitive-Behavioral Treatment of Chronic Tinnitus?”

²⁷ Aazh et al., “Tinnitus and Hyperacusis Therapy in a UK National Health Service Audiology Department.”

²⁸ Storch et al., “A Randomized Controlled Trial of Cognitive-Behavioral Therapy versus Treatment as Usual for Adolescents with Autism Spectrum Disorders and Comorbid Anxiety.”

superior canal. This surgery involves either plugging or resurfacing the canal to regulate the abnormal movement of the inner ear fluid. A case series study by Silverstein and colleagues analyzed the efficacy of transcanal surgery in individuals with hyperacusis. The procedure involved a transcanal placement of temporalis fascia on the round window membrane and stapes footplate.²⁹ Improvement was measured by testing patients' ULL and by administering the hyperacusis questionnaire. Patient 1, a 64-year-old male, reported significant improvement with respect to his hearing threshold and a 21-point improvement on HQ.³⁵ This patient also reported a higher ULL tolerance which was reported to be above 90 dB across frequencies ranging from 200 Hz-8000 Hz.³⁵ Patient 2, a 75-year-old female, reported a 13-point improvement on HQ. Patient 2 reported postoperative right ear ULL improvement of 8.67 dB across all tested frequencies.³⁵ Postoperative left ear ULL measurements reportedly improved by an average of 7.14 dB and were all above 90 dB.³⁵

7. Interventions and their Effectiveness

Given the intricate characteristics of ASD, a singular therapy or approach cannot cater to every individual across the spectrum. However, it is important to assess the efficacy and accessibility of these different approaches so that individuals with ASD can better evaluate available options. The table shown below provides a review of different studies assessing various interventions and their efficacy.

Table 1. Different Therapies and Their Efficacy in Treating Hyperacusis: Ear Protection, Desensitization and Tinnitus Retraining Therapy (TRT), Pink Noise Therapy, Cognitive Behavioral Therapy (CBT) and Counseling, Surgery.

Intervention	Reference	Study Design	Sample Size	Outcome measure	Findings
Ear protection	Vernon et al. [29]	Retrospective observational study	4,000	ULL	Patients who used methods of ear protection such as earplugs or noise-canceling headphones presented exacerbated symptoms of hyperacusis. This was presented by the lowered levels of uncomfortable loudness levels (ULL).
Desensitization and TRT	Jastreboff [31]	Retrospective analysis	263	Questionnaire	75% of patients reached the criteria of significant improvement as defined above. More than 80% of patients using noise generators or hearing aids

²⁹ Silverstein, Wu, and Hagan, "Round and Oval Window Reinforcement for the Treatment of Hyperacusis."



					as a part of TRT reached the outlined significant level of improvement.
Pink noise therapy	Vernon et al. [29]	Cross-sectional observation study	30	Questionnaire	20 patients who responded to the questionnaire. 13 patients reported using these tapes systematically and 7 patients (54%) reported improvement in their hyperacusis.
CBT, counseling,	Aazh and Moore [33]	Cross-sectional observation study	92	Questionnaire	Based on survey responses, the highest mean score for most effective intervention method was counseling (Mean = 4.7, SD = 0.6), followed by education (Mean = 4.5, SD = 0.8), CBT (Mean = 4.4, SD = 0.7), and hearing tests (Mean = 4.4, SD = 0.9). Only 6% of responders rated counseling as 3 or below. In contrast, bedside sound generators, hearing aids, and wideband noise generators were rated as 3 or below by 25%, 36%, and 47% of participants, respectively.
CBT	Storch et al. [34]	Randomized control trial	31	Pediatric Anxiety Rating Scale (PARS), Anxiety Disorders Interview Schedule for Children and Parents (ADIS-C/P), Clinical Global Impression-Severity and -Improvement	Participants randomized to CBT showed superior signs of improvement compared to those receiving treatment as usual (TAU). 11 of 16 (69%) adolescents randomized to CBT were treatment responders, versus 4 of 15 in the TAU condition. Improvement was maintained at a 1-month follow-up for CBT



				scales (CGI-S and CGI-I), youth and parent-report measures of anxiety, internalizing and externalizing symptoms, and psychosocial impairment	responders.
Surgery	Silverstein et al. [35]	Case series study	2 patients (3 ears)	LDL, Hyperacusis Questionnaire	Results from the hyperacusis questionnaire improved by 21 (Patient 1) and 13 points (Patient 2). No surgical complications. No reported negative effects from the surgery. Patient 1 higher LDL tolerance which was reported to be above 90 dB across all tested frequencies. Patient 2 reported postoperative right ear LDL improvement of 8.67 dB across all tested frequencies. Postoperative left ear LDL measurements reportedly improved by an average of 7.14 dB and were all above 90 dB.

8. Conclusion

Advances in technology and intervention methods can improve the lives of people with ASD. Our knowledge of the etymology of ASD continues to grow; theories suggest this condition stems from genetics, aberrations in brain anatomy, sensory processing capacities, and more. Existing literature indicates that hyperacusis and decreased sound tolerance are common in people with ASD. In many cases, decreased sound tolerance points to the presence of ASD and is instrumental in diagnosing one with ASD. Hyperacusis is one of the many challenges individuals with ASD face. ASD is complex and varies among individuals. Therefore, comprehensive evaluations and diagnoses are crucial to ensuring that patients receive appropriate treatment. ASD treatment is crucial for ensuring that individuals with ASD can maintain a good quality of life and the same opportunities as their neurotypical peers. This



neurological condition can affect one's social life, communication, and mental health, and can ultimately affect their performance in social and academic domains. Different studies with varying criteria have not proven the effectiveness of AIT as a treatment. Studies have shown that ear protection is detrimental to improving hyperacusis. Sensitization methods like pink noise therapy and tinnitus retraining have shown promise for hyperacusis patients. CBT has also proven to be a beneficial form of therapy for individuals with hyperacusis and/or ASD. Surgery and medical procedures offer benefits for treating ASD, but they might not be widely available. CBT and forms of desensitization are currently the most effective forms of therapy for ASD-affected individuals struggling with audio sensitivity. Making sure these forms of intervention are accessible is also very important to promote well-being in the ASD community. Our understanding of ASD and correlated neurological disorders continues to evolve and will better the lives of those with ASD. Ongoing research helps professionals enhance interventions for ASD and hearing-related issues.

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