Listening Issues in Autistic Students: Are We Doing Enough?

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ABSTRACT

Purpose: Despite the presence of normal, pure-tone hearing sensitivity, many students diagnosed with autism spectrum disorder (ASD) exhibit listening challenges relative to neurotypical peers, particularly in noisy environments like school classrooms. This literature review and exploratory survey aimed to (1) summarize evidence-based strategies to improve listening abilities in autistic individuals and (2) describe school-based, hearing-related services currently provided to autistic students.

Method: A review of the literature was conducted to document evidence-based strategies used to improve listening deficits in individuals with ASD and normal-hearing sensitivity. A nationwide survey was completed by educational audiologists and other school personnel to examine methods used to document observed listening abilities and hearing-related services provided to children with ASD.

Results: The literature review provided strong evidence to support the use of remote-microphone technology and auditory training to improve listening deficits in individuals with ASD. Survey responses revealed few audiologists are aware of the classroom listening difficulties of autistic students, while most educational personnel observe listening issues in the majority of their students. Few students with ASD and normal-hearing sensitivity receive services from school audiologists or use remote-microphone technology.

Conclusion: Although there is strong evidence to support the use of remote-microphone technology and auditory training for improving listening abilities, few school-aged children with ASD receive these interventions. Identifying ways to increase access to school-based hearing technology and services, such as increasing awareness of the listening issues and improving communication between teachers and audiologists, may optimize classroom listening for students with ASD.

INTRODUCTION

Estimates from the Centers for Disease Control and Prevention suggest 1 in 44, eight-to eleven-year-olds are diagnosed autism spectrum disorder (ASD) (Maenner et al., 2021). As a result, autistic students represent a high proportion of the school-aged population, and most will require special education services. The Individuals with Disabilities Education Act (IDEA; 2004) defines ASD as a developmental disability significantly affecting verbal and nonverbal communication, social interaction, and educational performance. In addition, the multisensory processing deficits common in autistic students may be associated with academic underachievement (Ashburner et al., 2008; Crasta et al., 2020; Tomchek & Dunn, 2007). More specifically, on the Short Sensory Profile (SSP; McIntosh et al., 1999), a caregiver questionnaire that rates behaviors across seven sensory domains, the large proportion of autistic children who displayed sensory-seeking behaviors and poor auditory filtering (i.e., ability to hear and complete tasks in the presence of extraneous background noise) had poorer academic performance (Ashburner et al., 2008).

Listening Issues in Children Diagnosed with ASD

Despite the presence of normal, pure-tone hearing sensitivity (NH), many autistic children exhibit abnormal listening abilities on parent or self-report questionnaires and auditory test measures (e.g., Rance et al., 2014; Schafer et al., 2020a; Schelinski & von Kriegstein, 2019). Listening difficulty may be defined as a reported deficit recognizing sounds or understanding speech (Dillon & Cameron, 2021). As shown in Table 1, when compared to neurotypical peers, deficit areas in autistic individuals who are high functioning include, but are not limited to, speech recognition in background noise, temporal processing, spatial stream segregation (i.e., benefit from separating speech from noise), binaural integration (i.e., dichotic processing), language-focused auditory processing, and parent/self-reported listening difficulties in various situations. Similar parent-observed auditory issues are reported in autistic children who are lower functioning and cannot complete behavioral test measures. For example, in Tomchek and Dunn (2007), parents of young autistic children reported significantly poorer auditory filtering, poorer visual/auditory sensitivity, and higher under-responsiveness/sensation seeking than parents of neurotypical children. In summary, listening difficulties are a hallmark of ASD and may be impacted by a number of variables including cognitive, language, and attention deficits (Dillon & Cameron, 2021; Rance et al., 2014; Schafer et al., 2020a; Schelinski & von Kriegstein, 2019; Tomchek & Dunn, 2007).

Study Rationale

Despite the strong evidence showing auditory and listening difficulties in NH autistic individuals, standard educational recommendations do not exist regarding the most appropriate auditory interventions. Furthermore, to date, no data are available to examine the types of auditory listening assessments and interventions currently provided to NH autistic students. As a result, this literature review and school-based survey aimed to answer the following two research questions:

(1) What evidence-based intervention strategies exist to improve behavioral listening and auditory abilities in NH autistic individuals?

(2) What school-based, hearing-related assessments and services are currently provided to NH autistic students?

Overall, this study was expected to identify ways to increase access to school-based services and hearing technologies to optimize classroom listening in this large student population.

Table 1. Observed and Measured Behavioral Listening and Auditory Deficits in Autistic Individuals with Normal-Hearing Sensitivity Compared to Neurotypical Peers

Deficit Area	Author, Year	Ages in Yrs (N)	Results
Speech Recognition in Noise	Rance et al., 2014	R=8-15 (N=20)	-Word recognition thresholds in noise significantly poorer than controls
	Schafer et al., 2020b	R=7-23 (N=21)	-Sentence-in-noise thresholds in noise 0.7 (adults) – 2.4 (children) dB worse than controls
	Schelinski & von Kriegstein, 2019	R=20-51 (N=16)	-Sentence-in-noise thresholds 1.5 dB worse than controls
Spatial Stream Segregation	Rance et al., 2014	R=8-15 (N=14)	-Significantly lower spatial advantage (i.e., benefit from separating speech from noise) than controls
	Schafer et al., 2020b	R=7-23 (N=21)	-Significantly lower spatial advantage than controls
Binaural Integration: Dichotic Processing	Schafer et al. 2020b	R=7-23 (N=21)	-Significantly poorer recognition of dichotic digits and words and large score ear differences between ears than controls
Language-Focused Auditory Processing	Schafer et al. 2020b	R=8-15 (N=21)	-Significantly poorer phonological blending number memory reversed, word memory, sentence memory, and auditory reasoning than controls
Auditory Temporal Processing	Rance et al., 2014	R=8-15 (N=14)	- Significantly poorer amplitude modulation detection thresholds compared to controls

Methods

Although the researchers respect all preferences regarding subject identification, to attempt to avoid ableist language, the researchers will use identity-first language to identify autistic individuals throughout the remainder of this manuscript (Bottema-Beutel et al., 2021).

Literature Review and Effect Size Calculations

The review of evidence-based strategies to improve listening abilities in autistic children was conducted using the five recommended steps in Khan et al. (2003): Frame question, identify relevant work, assess quality of studies, summarize the evidence, and interpret the findings. Studies included in the review (1) had more than one NH subject diagnosed with ASD, (2) examined the efficacy or effectiveness of auditory-focused intervention(s) to improve listening in one or more areas listed in Table 1, and (3) were published on or after 2010 to represent contemporary hearing technologies. Case studies, single-subject designs focused on applied behavior analysis or music therapy, and studies on auditory integration training were excluded because a Cochrane Library Systematic Review of six randomized controlled trials that found no evidence to support this type of intervention (Sinha et al., 2011). Studies included in the literature review were identified with electronic databases (i.e., PubMed; Google Scholar; ERIC; Science Direct) as well as manual searches through peer-reviewed journals and reference lists in articles published between January 2010 and October 2021. Search terms included "autism," "auditory training," "dichotic," "classroom," "school," "listening," "remote microphone," "FM system," and "frequency modulation system." The investigators reviewed over 330 abstracts or full-text articles, and ultimately, 12 articles met the inclusion criteria (Tables 2 and 3).

In addition to summarizing results of studies, effect sizes between study test conditions were provided in Tables 2 and 3 when they were available in a published manuscript, could be calculated using individual data available in a manuscript, or could be calculated from data stored by the first author. Effects sizes are important to consider, along with results of statistical analyses (i.e., p values), because they indicate the magnitude of improvement after an intervention while considering the variability with in a sample (Sullivan & Feinn, 2012). Because all studies used a within-subjects, repeated-measures design, average performance between the test conditions was likely to be correlated. As a result, modified effect size and variance formulas for correlated measures determined using formulas from Lenhard and Lenhard (2016) and Dunlap et al. (1996). Correlations between conditions, which were required as part of the effect size calculation, were estimated using individual data from several studies (Schafer et al., 2013, 2016, 2019a). Small (0.2), medium (0.5), and large (0.8) effect sizes were determined using criteria from Cohen (1988).

Survey Items and Dissemination

Survey items were developed by the authors based on their previous research and professional experience in school-based services for students with hearing loss or other listening issues. The survey included statements and questions focused on respondent characteristics, students served, services provided to NH autistic students, listening issues in this population (i.e., reported deficit recognizing sounds or understanding speech), types of listening-skill evaluations used, and barriers to providing remote microphone (RM) hearing assistance technology for this population, a common assistive technology provided by educational audiologists. A full list of survey questions is provided in the appendix. As indicated in the results section, a few survey questions were only directed to educational personnel who would be more aware of student performance in the classroom. An online survey draft was developed in Qualtrics (2005). Given the anonymous nature of this survey, it qualified for an exemption from the University of North Texas Institutional Review Board.

In March 2021, the online survey was distributed nationally in the United States to educational audiologists and other school personnel via social media platforms, e-mail communication, and the Educational Audiology Association Listserv. The results of this study represent all available data from survey responses collected through August 30, 2021. Sample sizes (N) vary across the survey questions because some questions allowed respondents to select all responses that applied to their schools, and some questions did not apply to every respondent.

Results

Literature Review

The majority of studies in Tables 2 and 3 included only high-functioning school-aged children with no intellectual disability, with the exception of Keller et al. (2021) who conducted observations with lower-functioning preschoolers. Many participants in the studies were diagnosed with multiple disabilities including attention-deficit hyperactivity disorder and anxiety disorder. As a result, auditory listening difficulties may be attributed to a combination of factors (e.g., cognition, working memory, attention) and disabilities.

Table 2 summarizes studies that used dichotic, speech-in-noise, and temporal training to significantly improve multiple areas of auditory processing in autistic children and young adults. In the Kozou et al. (2018) study, large pre-post dichotic training effect sizes were calculated for trained (dichotic digits) as well as untrained auditory areas (filtered words, auditory figure ground, phonological awareness). Similarly, in Ramezani et al. (2021), temporal training (i.e., interval detection in noise and temporal pattern detection exercises) improved an untrained area, speech recognition in noise, which yielded a very large pre-post training effect size. In Schafer et al. (2019b), participants completed dichotic training, speech-in-noise training, and used a bilateral RM system over 12 weeks. Results showed significantly improved auditory performance and medium to large pre-post training effect sizes across multiple trained and untrained areas of auditory function (Table 2).

Table 2. Summary of Studies Using Auditory Training to Remediate Auditory Issues in Autistic Individuals with Normal-Hearing Sensitivity

First Author, Year (age range)	Group(s) (N)	Type of Training: Results
Denman, 2015 (10-11 yrs)	Autistic (N=3)	Dichotic training: - Individual improvements in dichotic words, dichotic sentences, and slight improvement in working memory
Kozou, 2018 (7-12 yrs)	Autistic (N=14)	Dichotic training: - Improved dichotic digits, non-dominant ear, **d= 1.0** - Improved filtered words, both ears, **d= .7** - Improved auditory figure ground, **d= .8-.9** - Improved competing words, **d= .8-1.4** - Improved phonological awareness
Ramezani, 2021 (10-16 yrs)	Autistic N=14	Temporal training with interval detection in noise and temporal pattern detection exercises: - Improved word recognition in noise, **d= 1.**8
Schafer, 2019b (7-21 yrs)	Autistic (N=15)	Dichotic training + speech-in-noise training + Bilateral RM: - Improved sentence recognition in noise, **d=1.2**, and acceptance of noise, **d= -.92**, when RM in use - Improved general auditory processing on 6/9 subtests, **d= .43-1.5** - Improved spatial stream segregation, **d= -.58** - Improved 2-pair dichotic digits, non-dominant ear, **d= 1.1** - Improved dichotic words, non-dominant ear, **d= 1.**5

Note. ASD=autism spectrum disorder; RM=ear-level remote microphone system.

Table 3 provides an overview of studies conducting auditory assessments before and after a trial period with RM technology in autistic children and young adults, as well as participants with other disorders, including the Schafer et al. (2019b) study discussed above that combined training with RM use. Across the studies, medium, large, and very large pre-post effect sizes were calculated showing improvements in word and sentence recognition in noise, spatial stream segregation, on-task behaviors and listening abilities observed by teachers, parent and self-perceived listening abilities, acceptance of higher noise levels, binaural integration (dichotic stimuli), listening comprehension, and several areas of general auditory processing (i.e., hierarchy of auditory processing skills on Test of Auditory Processing Skills; Martin & Brownell, 2005). Other areas of noteworthy improvement included examiner-observed functional listening performance in young children (3-4 years; Keller et al., 2021), better phonological processing (Wilson et al., 2021), and lower salivary cortisol levels during RM use (Rance et al., 2017).

Educational Survey Results

General Respondent Information

The 168 survey respondents included 112 educational audiologists serving students in 36 different states and 56 educational personnel serving students in 17 different states. The professional roles of the educational personnel included special education teachers (60%), speech-language pathologists (22%), other school personnel (13%), general education teachers (2%), and teacher's aides/assistants (2%). Respondents served a single or combination of age groups including students enrolled in preschool, elementary, middle school, and high school. The majority of educational personnel were serving elementary students (62%), and educational audiologists served similar numbers of students in all four aforementioned age groups. Most respondents served only public schools (60% audiologists; 89% educational personnel) with the remainder serving private schools or a combination of public and private schools. All respondents served or taught NH autistic students.

Educational Characteristics of NH Autistic Students

According to the majority of educational personnel, greater than 75% of their NH autistic students had Individualized Education Plans (IEP) with the remainder having 504 plans. Due to the COVID-19 pandemic, almost all respondents (97%) served a combination of students who were educated in person or remotely. Figure 1 shows estimated percentages of NH autistic students with listening issues in the classroom. The majority of educational personnel reported that most NH autistic students (> 60%) have listening issues, while most educational audiologists did not know whether or not these students struggled to listen in the classroom.

Table 3. Summary of Studies Using Remote Microphone Technology to Improve Auditory Issues in Autistic Individuals and Those with Other Disorders

First Author, Year (age range)	Group(s) (N)	Type of Intervention: Results
Keller, 2021 (3-4 yrs)	ASD (N=8)	Classroom audio distribution system: - Examiner-observed functional listening performance
Rance, 2014 (8-15 yrs)	ASD (N=8-20)	Bilateral ear-level FM: - Improved word recognition in noise (n=20), **d=.4** - Improved self/parent-reported listening/communication (n=8) - Improved teacher-reported listening/comprehension, classroom behavior, and general attentiveness (n=8)
Rance, 2017 (6-16 yrs)	ASD (N=26)	Study A – Bilateral ear-level FM (n=10): - Improved word recognition in noise, **d=1.2** - Lower salivary cortisol (stress) - Improved self-reported listening in noise and ease of communication Study B - Classroom audio distribution system (n=16): - Lower salivary cortisol (stress)
Schafer, 2013 (9-12 yrs)	ASD, ADHD (N=10)	Bilateral ear-level FM: - Improved sentence recognition in noise, **d= 2.0-2.8** - Improved observed on-task classroom behaviors, **d= .8-1.3** - Improved teacher-reported listening behaviors in noise, **d= .4** - All but one child wanted to continue using RM
Schafer, 2014 (6-11 yrs)	ASD, SLI, ADHD, LD, APD (N=7-12)	Bilateral and unilateral ear-level FM: - Improved sentence recognition in noise, **d= 2.3** - Improved self- and teacher-reported listening ability at school - Improved self- and parent-reported listening ability at home
Schafer, 2016 (6-17 yrs)	ASD (N=12)	Bilateral ear-level RM: - Improved teacher-, **d= .3-1.2**, parent-, **d= .6-1.5**, and self-reported, **d= 1.3**, listening at home, in noise, in social situations, and at school - Improved sentence-in-noise thresholds, **d= -1.4** - Improved acceptable noise levels, **d= -1.4** - Improved listening comprehension, **d= 1.0**
Schafer, 2019a (7-23 yrs)	ASD (N=19)	Bilateral ear-level RM: - Improved sentence recognition in noise, **d= 1.1** - Improved self-reported sensory processing, **d= -.3 adults, d= 1.1 children** - Improved self-reported classroom listening, **d= .6**
Schafer, 2019b (7-21 yrs)	ASD (N=15)	Bilateral ear-level RM + dichotic training + speech-in-noise training: - Improved sentence recognition in noise, **d= 1.2**, and acceptance of noise, **d= -.92**, when RM in use - Improved general auditory processing on 6/9 subtests, **d= .4-1.5** - Improved spatial stream segregation, **d= -.6** - Improved 2-pair dichotic digits, non-dominant ear, **d= 1.1** - Improved dichotic words, non-dominant ear, **d= 1.5**
Wilson, 2021 (7-8 yrs)	ASD (N=13)	Classroom audio distribution system: - For the group who used the system: Better teacher ratings of listening and learning behaviors, better phonological processing

Note. **d**=effect sizes between no-RM and RM test conditions; APD=auditory processing disorder; ASD=autism spectrum disorder; ADHD=attention-deficit hyperactivity disorder; FM=frequency modulation system; LD=language disorder; RM=ear-level remote microphone system; SLI=specific language impairment.

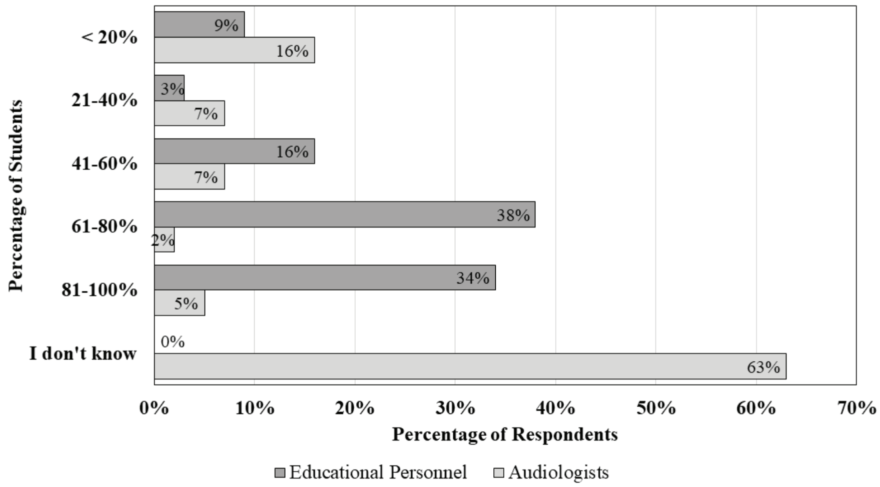

Figure 1. Estimated percentages of students with ASD and normal-hearing sensitivity with listening issues in the classroom reported by educational audiologists and educational personnel.

Assessments and Services Provided to NH Autistic Students

The majority (75%) of case managers for the NH autistic students were special education teachers with the remainder of managers serving as speech-language pathologists, autism specialists, and other school professionals (i.e., diagnostician, school psychologist, social worker). When the educational personnel were asked to estimate the percentage of NH autistic children on their caseload who received services from a school-based or contracted audiologist, the overwhelming majority indicated none (72% of respondents) or less than 25% of students (19% of respondents). Figure 2 summarizes the specific educational audiology services provided to NH autistic students with the most frequent service including hearing screenings (24%) and audiological evaluations (26%). No audiologists provided auditory training, although this intervention is within their scope of practice in most states and by national certifying organizations.

In Figure 3, educational audiologists and personnel reported the type of specific methods to assess listening skills in NH autistic students. Overall, the most widely used methods to evaluate listening skills include documentation of parent and teacher concerns with questionnaires or interviews, classroom observations, and speech-language/communication evaluations. Included in the "other test measures" are functional listening evaluations (Johnson & VonAlmen, 1993), dichotic testing, assistive technology evaluations, yearly audiologist screenings, hearing screenings from the nurse, and academic and cognitive testing.

Provision of RM Hearing Assistance Technology for Autistic Children with NH

Only 35% of the educational personnel report that hearing assistive technology, such as RM systems, was ever considered for their NH autistic students. Both educational audiologists

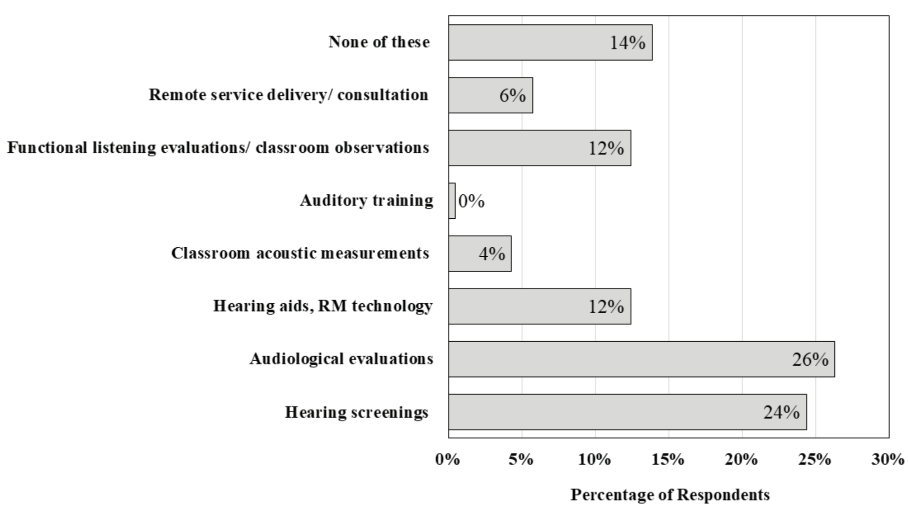

Figure 2. Educational audiology services provided to students who have normal-hearing sensitivity and ASD.

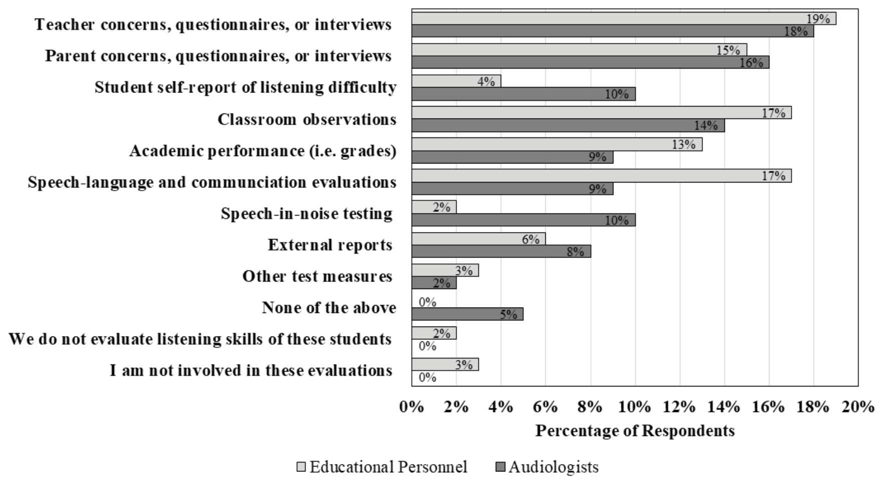

Figure 3. Methods to assess listening skills in students who have normal-hearing sensitivity and ASD.

and personnel indicated that, when RM technology is used, approximately 40% of students used personal RM system worn on the ear, 40% used classroom soundfield systems (i.e., classroom auditory distribution systems), and the remainder used desktop soundfield or other types of systems. Barriers to providing RM hearing assistive technology to this population are outlined in Figure 4. Over one-third of educational personnel reported they are not involved in these RM technology decisions, and a large proportion of educational audiologists and personnel (27%; 39%) indicated that students had no documented listening deficits. In addition, 26% of educational audiologists indicated device rejection as a barrier. Additional barriers reported by individual respondents are provided in Table 4. Finally, Table 5 outlines other accommodations and technologies provided to NH autistic students.

Discussion

The Problem

Despite the presence of NH, most autistic children and young adults experience significant listening challenges as indicated in many peer-reviewed studies including those cited in Table 1. These auditory deficits are associated with notable consequences that include, but are not limited to, academic underachievement; over or under responsiveness to auditory stimuli; poor teacher-

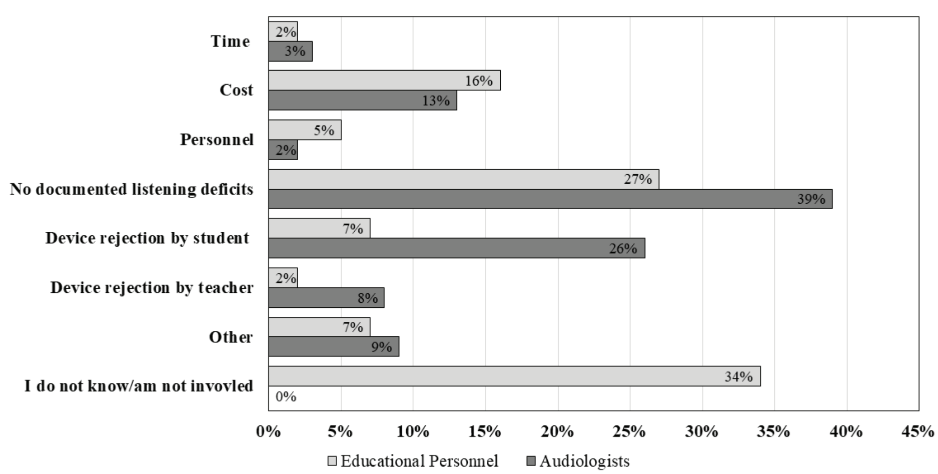

Figure 4. Barriers to providing RM hearing assistive technology to students who have normal-hearing sensitivity and ASD.

Table 4. Additional Barriers to Providing RM Technology Reported by Educational Audiologists and Personnel

- Audiology does not provide equipment to students with normal hearing
- Students are not being referred due to lack of understanding student needs by school personnel/ parents
- No funding for students without hearing loss
- Already have difficulty serving all children who are deaf and hard of hearing
- Lack of access to hearing tests
- Lack of RM benefit during trial period or device rejection
- Lack of staffing and inability to serve individuals with normal hearing, unless diagnosed with a central auditory processing deficit
- Lack of education regarding benefit of these devices
- No team or evaluation procedures for remote microphone need
- No access to technology in classroom
- Personally, as a special education teacher with a masters in applied behavior analysis, I feel shocked that I have never thought about using a device

RM=remote microphone technology

Table 5. Accommodations and Other Technologies Provided to Autistic Students with Normal-Hearing Sensitivity

- Visual communication systems or choice boards
- Notetakers/organizers and checklists, especially to transition between classes
- Targeted or specialized seating away from auditory or visual distractors
- Extra time to complete tasks; modified assignments
- Special chairs, bands on chairs, pressure vests, and fidgets
- Breaks/quiet time
- Text-to-speech or speech-to-text technology
- Augmentative and alternative communication devices
- Paraprofessional support
- Essentially any accommodation necessary for their academic success

and parent-observed listening behaviors; limited use of spatial auditory cues (i.e., benefit from spatially separating speech/noise); increased stress levels relative to peers; and poorer language-focused auditory processing (i.e., phonological blending number memory reversed, word memory, sentence memory, and auditory reasoning) (Ashburner et al., 2008; Crasta et al., 2020; Rance et al., 2014, 2017; Schafer et al. 2020b; Tomchek & Dunn, 2007). In addition, the majority of NH autistic individuals have poor auditory filtering and speech recognition deficits in the presence of background noise (Rance et al., 2014; Schafer et al., 2013, 2014b, 2016, 2019a, 2019b, 2020a, 2020; Schelinski & von Kriegstein, 2019), which is particularly concerning given most classrooms have poor acoustics (Knecht et al., 2002). Given these well-documented auditory deficits, many NH autistic students will exhibit educational need for auditory-focused, school-based special education services and interventions. However, to document this educational need, sensitive and feasible assessments must be used, several of which are listed in Table 1.

Potential Solutions

The first aim of this study sought to review evidence-based intervention strategies to improve behavioral listening and auditory abilities in NH autistic individuals. As summarized in Tables 2 and 3, multiple studies support the use of auditory training (dichotic and temporal) and RM technology to improve behavioral and observed auditory performance across multiple domains. Using pre-post data, medium to very large effect sizes were calculated across multiple studies that assessed the potential benefits of auditory training and RM systems, providing strong evidence that these strategies may improve auditory function in NH autistic students. In addition to the behavioral improvements listed in Tables 2 and 3, several other studies show that auditory training and use of RM technology result in objective auditory changes as measured with electrophysiological responses to speech stimuli (Gopal et al.,2021; Ramezani et al, 2021; Russo et al., 2010).

Are We Utilizing These Solutions?

The second, more exploratory aim of this study, was to examine existing school-based, hearing-related services currently provided to NH autistic students. Although the sample sizes were limited, survey data from educational audiologists (N=112) and educational personnel (N=56), consisting of mostly special education teachers and speech-language pathologists, highlight some important considerations for managing this population in the schools. First, as expected, most of these students (75%) have an IEP, which, guarantees them special education services including assistive technologies to access the curriculum. Because most autistic students have auditory issues (Table 1) that are likely to interfere with auditory-focused learning (e.g., teacher lecture, group work), strategies to mitigate auditory issues (Tables 2 and 3) should be provided in a student's IEP.

Second, the auditory issues reported in the literature are confirmed with the survey results (Figure 1). Auditory issues are present for over 60% of the of NH autistic students represented in the survey; however, surprisingly, over 60% of audiologists did not know if their autistic students even had listening issues. Figure 1 highlights the potential disconnect between personnel working at the school on a daily basis versus related service providers who may not routinely observe the needs of their autistic students in the dynamic classroom environment. Clear documentation of potential listening deficits in individual students is critical, and measures such as functional listening evaluations, classroom observations, speech recognition in noise, parent/teacher interviews, and parent/teacher questionnaires may be used to document educational need (Schafer et al., 2014a, 2016)

Third, educational personnel reported that very few of their NH autistic students were receiving any services from a school-based or contracted audiologist (72% of respondents said none). Figure 2 suggests that audiology services are limited primarily to audiological evaluations and hearing screenings (50%) with limited use of listening evaluations (12%) or the evidence-based interventions including RM technology (12%) and auditory training (0%). When listening evaluations are utilized, they consisted of mostly of parent/teacher questionnaires or interviews, classroom observations, and speech-language/ communication evaluations (Figure 3). Few students completed speech recognition in noise testing, which in several research studies, detected significant differences between autistic individuals relative to a control group (Table 1). Auditory- and listening-focused assessments and interventions are critically needed for this population because the evidence clearly shows that most NH autistic students have auditory issues that impact listening in the classroom (Table 1; Figure 1).

Finally, less than one third of respondents indicated that RM technology was ever considered for NH autistic children. The primary barriers to this technology included device rejection and no documented listening deficits (Figure 4), with additional barriers (Table 4) related to funding and services for students with "normal hearing", staffing issues, and lack of education regarding the potential benefits of RM technology for this population. While device rejection may occur in some children who have tactile sensitivities, the studies included in this literature review showed device rejection was relatively limited in autistic children who are higher functioning. As a result, there may be educational strategies such as social stories, video modeling, education about the device, and listening games that may increase device acceptance (Schafer et al., 2013). Furthermore, emerging evidence suggests soundfield systems also provide benefits to both lower and possibly even higher-functioning autistic children (Keller et al., 2021; Wilson et al., 2021).

Study Limitations and Future Research

The primary limitations of the survey are related to the limited sample sizes in the survey, survey construction, and potentially relevant areas that were not addressed. As stated previously, despite our best efforts, the survey sample sizes were limited, particularly for the educational personnel. A larger sample might yield different results, although these preliminary results on hearing services for NH autistic students highlight critical issues related to the limited support they receive. Given that the survey was exploratory in nature, the reliability and validity of the survey instrument was not determined. In addition, this survey is unable to pinpoint the underlying mechanisms, cause(s), or contributors associated with classroom listening difficulties. Listening is very complex in nature, and difficulties may stem from numerous issues including receptive and expressive language disorders, executive function, auditory memory, and attention (Dillon & Cameron, 2021). All of these issues also may have impacted performance in the studies summarized in Table 1. Finally, there were aspects of school services for NH autistic students that were not assessed in this survey. Future research will need to more carefully consider the roles of each professional who serves autistic students (e.g., occupational therapist, speech-language pathologist, audiologist), whether any listening-focused auditory training is provided by speech-language pathologists, and whether any commonly-used school-based assessments may be used to document listening issues in this population. In addition, a follow-up survey will need to be conducted to examine school-based hearing services and technologies provided to other NH populations who would likely benefit from RM technology or auditory training, including those diagnosed with auditory processing disorder (APD), attention deficit hyperactivity disorder, Friedreich's ataxia, and dyslexia (Schafer et al., 2020a).

Conclusion

Individualized school-based services and supports are often needed to promote educational access for autistic students. Strong, peer-reviewed evidence exists regarding listening deficits of many NH autistic students, which may result in educational need for school-based services including hearing technology. Evidence-based interventions exist in the form of auditory training and RM technology, which can ameliorate some of the auditory difficulties faced by this school population. Unfortunately, however, according to the survey, these interventions are uncommon for NH autistic students, due in part to undocumented listening deficits, RM technology rejection, staffing issues to serve these students, or lack of education regarding the potential benefits of RM technology for this population. Increasing awareness of listening difficulties in this population and identifying ways to increase access to school-based hearing technology and services will ensure optimal classroom listening abilities in NH autistic students.

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Appendix. Survey Questions

General Respondent Information	• In what state(s) do you provide services? • What are the grade levels of the NH autistic students you serve? • How many public school districts/co-ops do you serve? • Do you serve any private schools?
Educational Characteristics of NH Autistic Students	• Estimate the percentage of NH autistic students in your school/on your caseload who have a 504 plan? • Estimate the percentage of NH autistic students in your classroom/on your caseload who have an Individualized Education Plan (IEP)? • Do you serve students remotely or in person? • What percentage of NH autistic students that you serve struggle with listening in the classroom?
Assessments & Services Provided to NH Autistic Students	• The case manager for the majority of NH autistic students in your district(s) include which of the following? • Estimate the percentage of NH autistic students in your school/on your caseload who receive services from a school-based or contracted audiologist? • Do you provide any of the following services to NH autistic students? • Which methods do you use for evaluating listening skills in NH autistic students?
Provision of RM Hearing Assistance Technology for NH Autistic Students	• Is hearing assistive technology, such as an FM system, ever considered for NH autistic students who are in your classroom/on your caseload? • If remote microphone hearing assistance technology (e.g., FM system) is an option • for NH autistic students, what types of systems are used? • If remote microphone hearing assistive technology is not provided for NH autistic students who are in your classroom/on your caseload, what are the barriers? • What other accommodations are provided for s NH autistic students?

Note. FM=frequency modulation; NH=normal hearing.