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ARTICLES

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>
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700 McKnight Park Drive, Suite 708, Pittsburgh, PA 15237
Phone: 800-460-7EAA (7322) ● Fax: 888-729-3489
www.edaud.org ● admin@edaud.org

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Hearing Aid and Hearing Assistive Technology Non-Use in Classrooms: A Survey of Teachers of the Deaf, Audiologists, and Speech-Language Pathologists

Kimberly Peters, PhD[1], Karen Anderson, PhD[2]

[1]Department of Communication Sciences and Disorders
Western Washington University
516 High Street MS 9171
Bellingham, Washington 98225
(360)-650-3206
Kimberly.peters@wwu.edu

[2]Director, Supporting Success for Children with Hearing Loss

ABSTRACT

Consistent hearing technology use is important for spoken language development for children who are deaf or hard of hearing (DHH). Schools need to be aware of risk factors for technology non-use in order to ensure that IEP and 504 accommodations are implemented and enforced throughout a child's education. The goal of this study was to describe use and non-use patterns of personal and classroom hearing assistive technology (HAT) for children who are DHH across a wide grade range. Eighty-six itinerant teachers of the deaf, educational audiologists, and speech language pathologists completed an anonymous online questionnaire about hearing aid and FM/DM (frequency modulation/digital modulation) use patterns for their caseloads during one academic year. Data for 1863 students, pre-K through 11th grade, were analyzed. Findings were consistent with previous research showing a high HAT non-use rate among school-age children who are DHH. Peaks for non-use for bilaterally aided children were kindergarten, 3rd, 6th, and 8th grade, with 6th grade being the most likely grade for hearing aid and FM/DM non-use. The predominant reason for non-use was social pressure; although children who spent more time with DHH peers were less likely to reject amplification.

INTRODUCTION

The importance of early identification and management of pediatric hearing loss is well documented in the literature (Ching, et al., 2013; Koehlinger, Van Horne, & Moeller, 2013; Moeller, 2000; Sininger, Grimes & Christensen, 2010; Stiles, Bentler, & McGregor, 2012; Yoshinaga-Itano, Sedey, Coulter, & Mehl, 1998). Early and consistent auditory access to the acoustic cues for speech is critical for spoken language acquisition for children who are deaf (Sharma, Spahr, Dorman & Todd, 2002) or hard of hearing (Dokovic, et al., 2014; Moeller, et al., 2010; Tomblin, et al., 2015; Walker, Holte, et al., 2015). Best practices for management of pediatric hearing loss suggest that children be screened for hearing loss no later than 1 month of age, assessed by a pediatric audiologist no later than 3 months of age, and fit with appropriate amplification and enrolled in early intervention no later than 6 months of age (Joint Committee on Infant Hearing, 2007). Audiologists recommend that school-age children who are DHH wear their hearing technology "during all waking hours" in order to develop spoken language at a typical rate compared to hearing peers and be successful in the classroom (Tomblin, Oleson, Ambrose, Walker & Moeller, 2015). Recent studies suggest that hours of use and appropriateness of hearing aid fitting (matching of targets to degree of hearing loss) positively influence vocabulary and morpho-syntactic development in preschoolers and school-age children who are hard of hearing (Tomblin, et al., 2015; Walker, Holte, et al., 2015).

Components of a free and appropriate public education

The Individuals with Disabilities Education Act (IDEA), Title II of the Americans with Disabilities Act (ADA) and Section 504 of the Rehabilitation Act of 1973 (Section 504) provide guidance on the obligations of public schools to meet the needs of children with disabilities. Per IDEA 2004, schools are required to provide a free and appropriate public education (FAPE) to all students, including those with disabilities (CFR Section 300.101). When the Individualized Education Program (IEP) team determines that amplification use is a necessary component for FAPE to occur, it is included in the child's IEP.

Students with sensory impairments such as hearing loss are also covered by Section 504 of the Rehabilitation Act, regardless of their eligibility for special education and related services under the IDEA. Section 504 regulations require that students with disabilities have an equal opportunity to participate in school and that they receive FAPE, consisting of regular or special education and related aids and services designed to meet their individual educational needs as adequately as the needs of nondisabled students (Pardeck, 2002). Per ADA Title II, an IEP or a 504 plan must consider the level of access, or effectiveness of communication, as compared to peers; schools must ensure that communication with children who are deaf is as effective as communication with children who are typically developing (Anderson, 2017). Consistent amplification and classroom assistive technology use is a central component of communication effectiveness and is fundamental to ensuring educational equity for children who are DHH. If students who are DHH are at risk for rejecting amplification, then IEP teams should include provisions within specialized instruction to educate parents and teachers about the importance of full-time hearing aid usage, and develop student skills for coping with the social issues that can arise when their peer group becomes a focus. If the student is *not* wearing amplification, then the IEP team should meet to review and discuss needed accommodations and supports.

Hearing aid non-use in the pediatric population

It is clear from recent research that a high percentage of school age children who are DHH resist wearing their hearing aids full time (see Munoz & Hill, 2015, for a review of the literature from 2008-2012). Direct observation of children in school showed that approximately one quarter of children in elementary and middle school were not wearing their hearing aids (Gustafson, Davis, Hornsby, and Bess, 2015). In a study of 290 children with mild to severe hearing loss across a wide age range (preschool through elementary school), 36% of parents reported that their children wore their hearing aids for fewer than four hours per day (Walker, McCreery, et al., 2015); in this study, hearing aid use time increased as children got older. Additionally, parents significantly overestimated hearing aid use, consistent with other studies (Munoz et al, 2014; Gustafson, Ricketts, & Tharpe, 2017). Research suggests that parents of children with mild losses tend to overestimate hearing aid use to a greater extent (Walker, McCreery, et al., 2015), as do parents of children in upper elementary grades (Gustafson, et al., 2015).

In addition to school age children, infants, toddlers, and preschoolers have been shown to be inconsistent technology users. Munoz, Blaiser, and Barwick (2013), in their study of 333 children age birth to 6 years of age, reported that 38% of parents of children birth to 18 months, 43% of parents of children 19-36 months, and 29% of parents of children 3 to 6 years of age reported hearing aid use less than all waking hours. Overall, fewer than 50% of children between the ages of birth to 6 years of age wore their hearing aids consistently. Likewise, Moeller, Hoover, Peterson, & Stelmachowicz (2009) in a prospective, longitudinal study that included 7 families of infants with hearing loss showed that only three families achieved full-time technology use by 16.5 months of age and were able to maintain consistent use.

Factors that influence hearing aid use patterns in pediatric patients

The research suggests a variety of reasons for non-use of hearing technology, and these reasons change with age. Moeller et al. (2009) found that toddlers were most likely to take off their hearing aids in the car, when playing outdoors, and when not closely supervised by care providers. With close supervision, consistent use (between "frequently" and "always") was reported by 16.5 months of age for 6 out of 7 families who participated in the study. In preschool and younger school age children (kindergarten through second grade), Walker, et al. (2013) showed that longer hearing aid use time was associated with age (preschoolers averaged 8.24 hours/day of hearing aid use, while 5- to 7-year-olds averaged 11.68 hours of hearing aid use per day); hearing levels (children with pure tone averages higher than 50 dB HL wore their technology for an average of 11.12 hours per day); and higher socioeconomic status (children with college educated mothers wore their technology 11.28 hours per day on average). Parents in this study reported that challenges in enforcing consistent hearing aid use in the infancy period were typically related to child state (e.g., temper tantrums, illness, fatigue). Some studies have shown better compliance at school versus at home (Fitzpatrick, et al., 2010).

As children move through school, social concerns have increasing influence on hearing technology use patterns (Elkayam and English, 2003; Keilmann, Limberger and Mann, 2007). A survey by Oticon (Gordey, 2016) of 94 pediatric audiologists and a teen focus group revealed that 85% of audiologists felt it was challenging to get teens to wear their hearing aid consistently; and 63% of audiologists said that finding a hearing aid that was cosmetically appealing was a challenge. When teens talked to audiologists, the teens' biggest complaints were the size of the hearing device (69%), and the performance of the hearing device (60%). Of high importance to teens in this study were cosmetics and connectivity to other devices. Students also resist wearing classroom assistive technology at high rates due to social pressure. Franks (2008) reported that 53% of students ages 8-18 years who rejected an FM/DM system in the classroom did so due to social reasons.

Hearing aid rejection may also be due to device function problems, as there is a high rate of hearing aid malfunction for school-age children (Diefendorf and Arthur, 1987; Elfenbein, et al., 1988; Elfenbein, 1994; Lipscomb, Von Almen, and Blair, 1992; Blair and Langan, 2000; Most, 2002), or to the perception that hearing aids are not helpful (Franks, 2008).

Finally, hearing levels and language ability appear to influence compliance with technology use. Children with normal hearing in one ear, or less severe hearing loss, have been shown to be more likely to reject their amplification at some point (Fitzpatrick, et al., 2010; Walker, et al., 2013; Munoz, et al., 2014; Gustafson, et al., 2015; Gustafson, et al., 2017). And children with poorer vocabulary were more likely to use hearing aids consistently than children with better vocabulary (Gustafson, et al., 2017).

Pediatric fitting practices and parent education practices vary, even among seasoned pediatric audiologists, which may account for some of the variability in use patterns. Walker, Spratford, Ambrose, Holte, and Oleson (2017) in a study of 113 children with mild hearing loss reported that, while 94% of children were fit with amplification, they were fit significantly later than children with moderate-to-severe hearing loss. Later fitting may result in some resistance by children who perceived they were hearing fine without technology. Meibos, et al. (2016) surveyed 349 pediatric audiologists about how they support parent learning in achieving consistent hearing aid usage for their preschool age children. They found that 90% of pediatric audiologists used data logging to monitor hours of use. Information *not* routinely provided to parents by audiologists included: how to access loaner hearing aids; available hearing aid accessories; available financial assistance; how to teach hearing aid management to other care providers; how to do hearing aid maintenance; and how to do a Ling 6-sound check. The majority of audiologists in this study reported a desire for more training in counseling skills to support parents with hearing aid management. Munoz, Preston, and Hicken (2014) conducted an exploratory study to examine hearing aid use time for 29 children between 6 months and 7 years of age, and to examine whether providing parents with hearing aid data logging information increased hearing aid use over time. Parents reported challenges with hearing aid retention, and lack of awareness about benefits of amplification. Parents also questioned whether or not hearing aids were effective. Collectively, these studies suggest a need for better support for parents in optimizing hearing aid maintenance and use.

The importance of classroom HAT

In addition to consistent hearing aid use, consistent use of functioning classroom hearing assistive technology is important for auditory language and academic access at school. It is well documented in the literature that children who are DHH demonstrate diminished speech recognition in background noise compared to their typically hearing peers as the signal-to-noise (S/N) ratio decreases (Finitzo-Hieber & Tillman, 1978; Shield & Dockrell, 2003; Jamieson, Kranjc, Yu, & Hodgetts, 2004; Blandy & Lutman, 2005; Sheild & Dockrell, 2008; Iglehart, 2009). Title II of the Americans with Disabilities Act requires schools to ensure that communication for students who are deaf or hard of hearing be as effective as communication for typical students (ADA Title II 28 C.F.R. 35.160(a)(1)). For a student who is DHH to have comparable access to teacher instruction as typically hearing peers, he or she would need to demonstrate speech recognition scores across listening conditions in the 90-95% range (Anderson, 2017). Despite this, mainstream unoccupied classroom noise levels often exceed those recommended by the American National Standards Institute and the Acoustical Society of America (ANSI, 2002; ANSI/ASA, 2010) for optimal speech recognition for young children with typical hearing and those with hearing loss (ASA, 2000; Crandell & Smaldino, 2000; Knecht, Nelson, Whitelaw & Feth, 2002; Nelson, Soli, & Seltz, 2003). For this reason, consistent FM/DM use during the school day is critical for children who are DHH.

PURPOSE

While there is ample research examining hearing aid use patterns during the preschool years, the authors found only one study that examined hearing aid use patterns at school over a wide age/grade range (most studies include children in elementary school, but not in high school). In addition, in only one other study did researchers ask school personnel about their observations of children's hearing technology (personal hearing aids and FM/DM) use and non-use (Gustafson, et al., 2017); that study included 13 families and 10 teachers.

The specific goals of this paper were to describe technology use and non-use rates in a large group of children across a wide age range (preschool though 11th grade), and to explore reasons why personal hearing aids and classroom HAT were discontinued in preschool and school age children with hearing loss. This was accomplished through directly surveying specialists (teachers of the deaf, educational audiologists, speech-language pathologists and other professionals) regarding their caseload and experiences with rejection of hearing technology. This was a novel approach, as most studies to date have solicited information about classroom technology use from audiologists and/or parents, rather than the teachers who directly manage these children. Parent counseling and teacher coaching approaches may be informed and influenced by this knowledge. In addition, school administrators and professionals are responsible for overseeing and implementing IEPs and 504 accommodations for children who are deaf or hard of hearing. Information about time frame for resistance to technology and reasons for resistance to technology may be useful in developing and providing appropriate and mandated services for children who are DHH.

METHODS

This study used a cross-sectional survey design. Teachers of the deaf, educational audiologists, and speech-language pathologists who serve children who are DHH were invited via a website (*Supporting Success for Children with Hearing Loss)* to participate in an online survey about their caseloads for either the 2015-2016 or the 2016-2017 academic year. Information about the survey was shared, and participation encouraged, in the Supporting Success Newsletter, distributed to over 10,000 teachers of the deaf, audiologists, and speech-language pathologists from August 2016 through April 2017. Surveys were completed anonymously.

Participants

Teachers of the deaf, educational audiologists, speech language pathologists, and other professionals responsible for case management of children who were DHH in the public schools completed this survey. There were no other exclusionary criteria. Respondents only reported about children on their caseload that entered school with technology. Respondents only reported about children who wore a hearing aid on one or both ears. Children with cochlear implants were not represented in this study.

Instrument

The questionnaire (Appendix A) was developed by Karen Anderson, and included 10 broad questions, each with specific sub-questions about caseload characteristics (total number of students who used hearing aids and/or FM/DM); characteristics of students who refused to wear hearing aids and classroom assistive technology; use and non-use patterns; use and non-use reasons; and loaner technology availability. Reasons for technology rejection were chosen based on research suggesting that teenagers tend to reject hearing aids for social and/or cosmetic reasons (Elkayam and English, 2003; Franks, 2008; Gordy, 2016; Keilmann et al, 2007), parents may not fully understand the importance of full-time hearing technology use (Marnane and Ching, 2015), that there is a relatively high malfunction rate for hearing technology worn at school (Diefendorf and Arthur, 1987; Elfenbein, et al.,1988; Lipscomb et al, 1992; Elfenbein, 1994; Blair and Langan, 2000; Most, 2002), limited understanding of the benefits of amplification for children with mild and unilateral hearing loss (McKay, Gravel and Tharpe, 2008), and perceived lack of hearing aid benefit (Franks, 2008). Communication mode was not reported for purposes of this study.

Participants were asked to report about hearing aid and classroom FM/DM non-use across professionally established hearing loss categories to facilitate survey completion (e.g. standard audiologic categories were used to designate hearing levels rather than ranges of audiologic categories so that the survey would be as easy for participants to complete as possible, and so survey responses would not be biased by idiosyncratic understanding of hearing loss categories).

Teachers did not report on DHH students on their caseloads who did not wear technology at all (neither hearing aids nor an FM/DM).

Data Analysis

The data were entered into SPSS by the second author and descriptive information was analyzed. Due to the nature of the data (teachers described the characteristics of their student caseload generally and did not provided characteristics for individual students) correlational and/or regression analyses that included demographic information and other predictive factors could not be completed. Only mode scores for each question on the survey could be reported.

RESULTS

Eighty-six surveys were received from DHH teachers, educational audiologists and other professionals. Sixty-six itinerant teachers of the DHH, nine center-based teachers of the DHH, eight educational audiologists, one speech-language pathologist, one interpreter, and one DHH coordinator completed the survey. A total of 1863 students, pre-K through 11th grade were represented in the surveys returned.

Demographics of the respondents, including caseloads, are described in Table 1.

Table 1. Demographic Characteristics of Survey Respondents

Participants (N=86)			Caseload		
Students (N=1863)	n	%	M	range	median
Itinerant teacher of the Deaf	66	77			
Total caseload	1235	66	18.16	7-51	16.5
Center-based/resource room teacher	9	11			
Total caseload	102	5	11.33	4-32	8
Educational Audiologist	8	9			
Total caseload	458	25	52.75	10-150	49
Speech-Language Pathologist	1	1			
Total caseload	30	1.6			
DHH Coordinator submitting for group	1	1			
Total caseload	25	1.6			
Interpreter	1	1			
Total caseload	1				

Hearing Aid and Classroom Hearing Assistive Technology Use

Of the total caseload of 1863 students, hearing aid use was reported for 1848 students (99%). The remaining 15 students wore a different type of technology (for example, FM/DM as their primary amplification). Teachers did *not* report the total number of children on their caseloads with bilateral as opposed to unilateral hearing loss; however, they *did* report on the number of children in each hearing loss category who rejected their technology (for example, "of the non-users on your caseload, how many have unilateral loss with mild to moderate loss in the poor hearing ear?"). Professionals reported that 52% of students with bilateral hearing loss on their caseload wore both of their hearing aids full-time (missed none, or just an occasional school day, i.e., 3 times over the entire school year); 25.2% of students wore both hearing aids 3-4 times per week; 5.4% wore both hearing aids 1-2 times per week; 12% of students refused to wear their hearing aids at all; and 5.2% refused to wear one of their two hearing aids (See Figure 1).

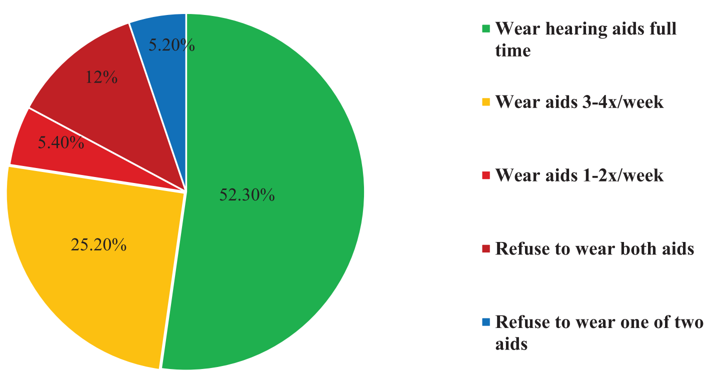

Figure 1. Hearing aid use (reported for 1848 students)

Of the total caseload (1863 students), FM/DM use patterns were reported for 1692 students (91%). Information about FM/DM use was left blank for the remaining 171 students. Participants responded that 534 out of 1692 students (31.6%) did *not* have FM/DM recommended for their use at all; 40% of students used FM/DM routinely (missed none or just an occasional school day); 7% used it only for certain classrooms; 9.2% used it only 1-2 times per week; and 12.3% refused to use FM/DM at all (see Figure 2).

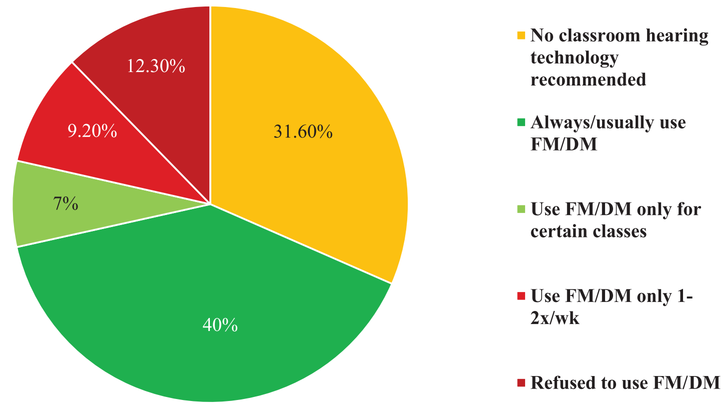

Figure 2. FM/DM Use (reported for 1692 students)

Hearing characteristics of students who refused to use personal amplification or FM/DM

Participants were asked about hearing loss characteristics of the students on their caseload who refused to wear hearing aids, or who only wore them occasionally. This comprised 624 students out of 1692 (36.8%). Of those 624 "non-users", hearing loss information was provided for 583 (93%). Participants reported that 17% of students who rejected their hearing aids had mild to moderate unilateral hearing loss, and 12% had severe to profound unilateral hearing loss. Of the children with bilateral hearing loss who were deemed non-users (416 students), hearing loss information was supplied for 405 (97%). Of this group, 16% had mild hearing loss, 20% had moderate hearing loss, and 15% had moderately-severe hearing loss in one or both ears. Teachers reported that 26% of non-users with bilateral hearing loss had a severe or profound hearing loss (see Figure 3).

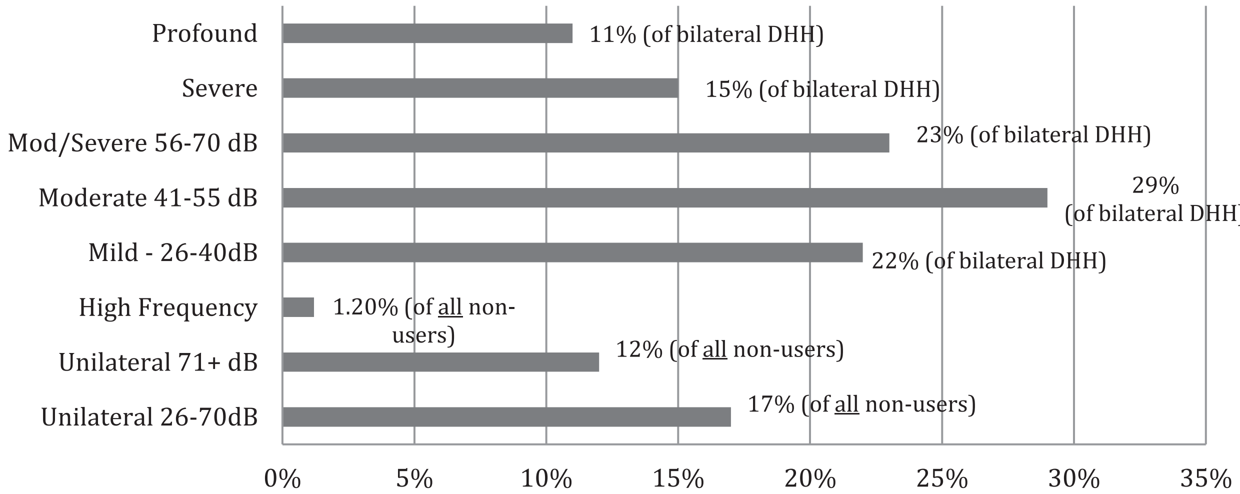

Figure 3. Degree of Hearing Loss for Hearing Aid Non-Users (405 students with bilateral loss and 178 students with unilateral or high frequency loss)

Participants were asked about hearing loss characteristics of the students on their caseloads who refused to use DM/FM in the classroom, or who only used it occasionally. Participants reported that 363 students out of 1158 (31%) refused to use their recommended FM/DM; out of these 363 students, hearing loss characteristics were provided for 347 students (96%). Children with unilateral hearing loss of any degree comprised 20% of non-users of FM/DM. Children with bilateral mild to moderate hearing loss comprised 39% of non-users, and children with severe to profound hearing loss comprised 26% of non-users (see Figure 4).

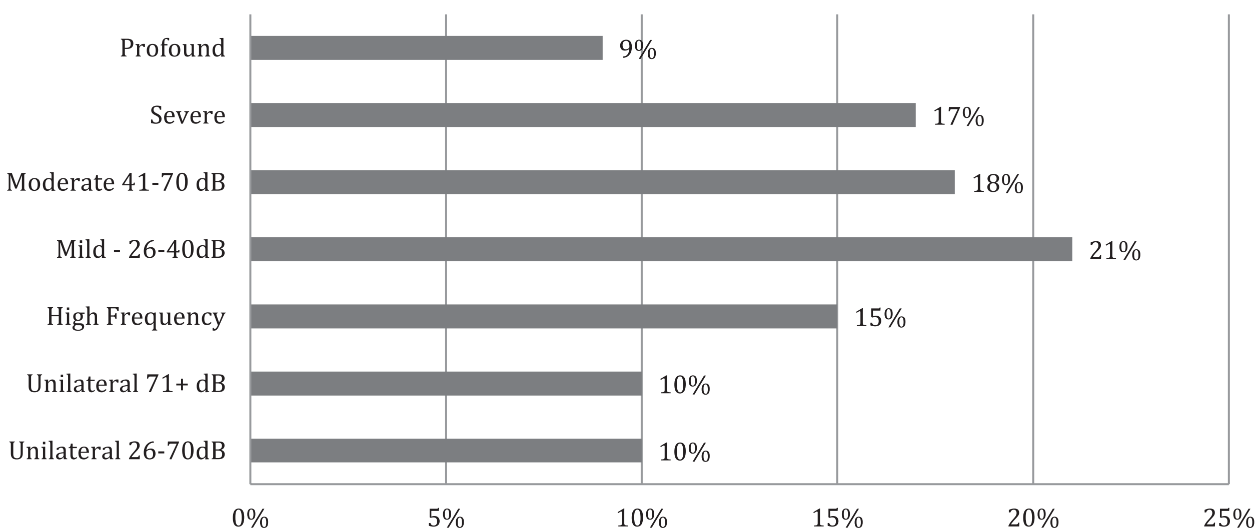

Figure 4. Degree of Hearing Loss for FM/DM non-Users (347 students)

Grade characteristics of students who refused to wear personal amplification or FM/DM

Participants were asked about the time frame (grade) in which students first began to resist using their hearing aids and/or FM/DM. Resisting technology was defined as the transition between using devices regularly to using them for “noticeably less time per week/ month”. Modes are reported for those participants who provided grade information. When analyzed based on degree of hearing loss, there was some variability in the grade at which children first began to resist technology. In addition, this question had the lowest response rate among teachers. Information about the grade at which non-use began was provided for only 26% of the 624 children identified as hearing aid non-users (163 students), and 37% of the 363 children identified as FM/DM non-users (135 students). Children with unilateral hearing loss or mild bilateral hearing loss were more likely than children with more severe hearing losses to resist using their hearing aids in preschool, although non-use for children with mild bilateral hearing loss was common in 2nd, 5th, and 7th grade as well. Children with more severe hearing losses (either unilateral or bilateral) tended to reject technology in later grades. Children with profound unilateral hearing loss or moderate bilateral hearing loss resisted using their hearing aids in 6th grade and their classroom FM/ DM between 5th and 6th grade. Children with bilateral moderate to severe hearing loss first began to resist personal hearing aids and classroom FM/DM in 7th grade; for children with severe hearing loss, the mode was 8th grade for resistance to hearing aid use and classroom FM/DM use. Overall, between preschool and 11th grade, the most common time for students to resist wearing their hearing aids was in 6th grade; 28 students resisted wearing their hearing aids beginning in 6th grade, out of a total of 163 for whom a grade was reported (See Figures 5 and 6).

Table 2: Non-use patterns by degree of hearing loss and grade

Degree of Hearing Loss	Initial Resistance to Hearing Aid Use	Number reported out of total number of non-users with this loss	Initial Resistance to FM/DM/HAT Use	Number reported out of total number of non-users with this loss
Mild Unilateral	Preschool	22 of 69 students	6th grade	15 of 33 students
Severe-Profound Unilateral	6th grade	13 of 50 students	6th grade	17 of 36 students
High Frequency	3rd grade	14 of 59 students	6th grade	14 of 53 students
Mild	3rd grade	34 of 91 students	6th grade	34 of 71 students
Moderate	6th grade	35 of 119 students		34 of 63 students
Moderate-Severe	7th grade	24 of 92 students	6-7th grade	25 students (no total for this degree HL)
Severe	8th	14 of 59 students	8th grade	14 of 51 students
Profound	5-6th grade	7 of 44 students	6th grade	16 of 32 students

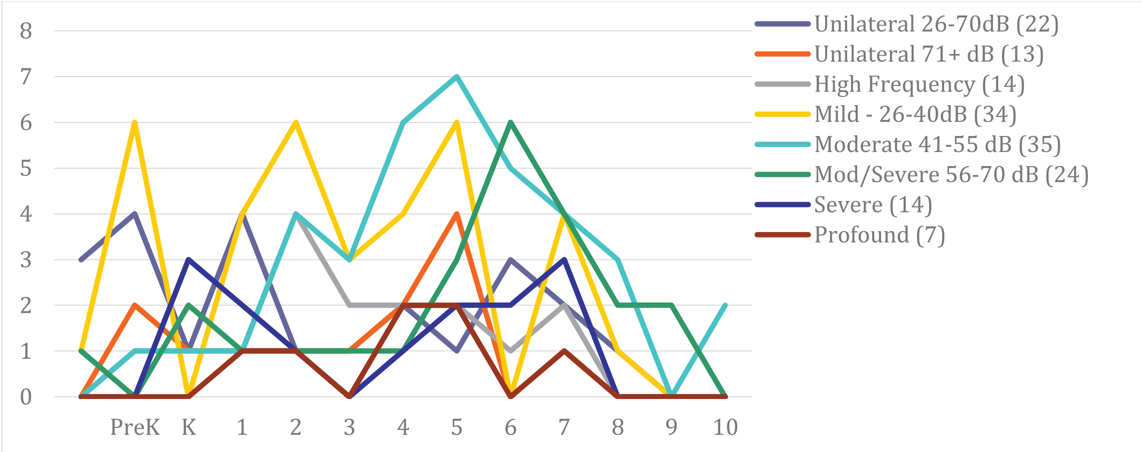

Figure 5. Grade When Resistance to Hearing Aid Use Began by Degree of Loss (number of students).

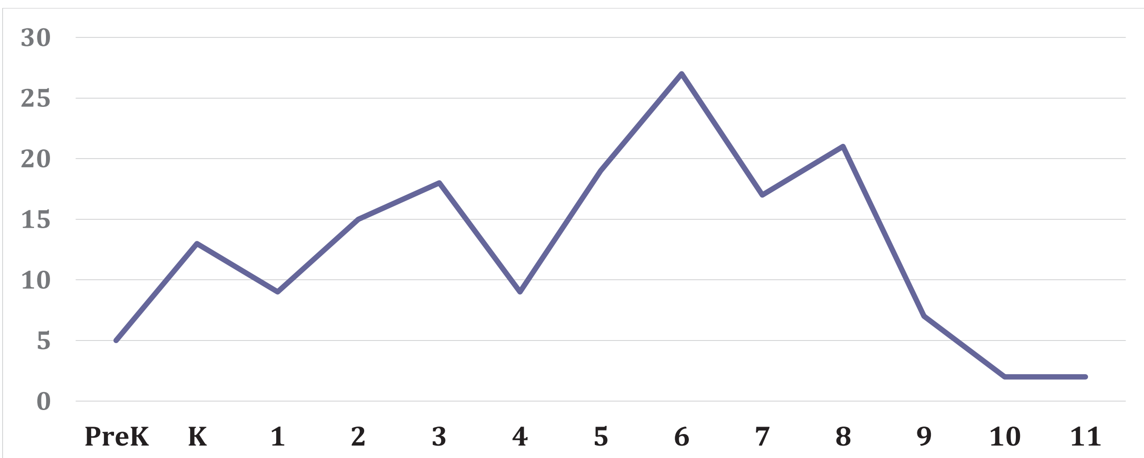

Figure 6. Grade when Resistance to Hearing Aid Use Began, Averaged Across Degree of Hearing Loss for 163 Students

Reasons for resistance to wearing personal amplification and FM/DM

Participants were asked why students began to resist wearing hearing aids based on six categories and across types and degrees of hearing loss. Options were (1) malfunction/repair issues, (2) comfort complaints, (3) family pressures, (4) social pressures, (5) low functioning (lack of perceived benefit or wear was not made a priority in the school setting), and (6) other. Out of a total of 624 students who resisted wearing their hearing aids at some point during school, a reason was provided for 161 students (26%). Participants reported that children in all categories of type and degree of hearing loss most often stopped wearing their hearing aids due to social pressures. Almost half of the students for whom a reason was reported (46.5%) cited social concerns/pressure as the reason for resisting or discontinuing hearing aid use at school.

Out of a total of 363 students who resisted wearing their classroom FM/DM at some point, a reason was provided for 180 students (50%). Participants reported that children in all categories of type and degree of hearing loss most often stopped wearing their hearing aids due to social pressures.

Participants were asked about only the students on their caseload that resisted wearing their hearing aid and/or classroom FM/DM for social reasons. Specifically, participants were asked how many of the students who infrequently used their technology were the only child in a school with hearing technology; how many were the only child in a school with hearing technology but come in contact with other students using hearing devices; how many students have at least one or two other students at school that they see during the week who use hearing technology; how many are in a group of 4 or more students at school that they see every school day but are primarily in mainstream classes; and how many are in a group of 4 or more students that they see every school day and may spend some of the time in mainstream classes (students who spend as much time with hearing children as with children wearing hearing technology). Participants reported on 439 students who stopped wearing their hearing aids for social reasons. Of those students, close to half (49%) were the only student in a school with hearing technology, whereas only 8% of non-users were in a cluster program in which they had regular contact with other students who were DHH.

DISCUSSION

Consistent hearing aid use, often defined by pediatric audiologists as "during all waking hours", is important for spoken language development. Schools need to be aware of risk factors for technology non-use in order to ensure that IEP and 504 accommodations are implemented and enforced consistently throughout a child's education, per IDEA, the ADA, and the Rehabilitation Act of 1973. The goal of this study was to describe use patterns and reasons for non-use of personal and classroom HAT for DHH children in school across a wide grade range. This study was unique in that it solicited feedback from a large number of school professionals who work with children who are DHH. Findings from this study were consistent with previous hearing aid data logging and parent report research showing a high technology non-use rate among school-age children who are DHH, particularly students with less severe degrees of hearing loss, and students with unilateral hearing loss. Similar to other research, participants reported that social factors influenced hearing aid and FM/DM use and non-use.

Hearing aid non-use patterns

Findings regarding hearing aid non-use suggest that almost half of students (47.7%) with any type or degree of hearing loss were not using their hearing aids full time at school as reported by a professional involved in case management. Of the students who refused to wear hearing aids at all, or who wore their hearing aids only 1-2 times per week, approximately one third were students with unilateral hearing loss. Students with bilateral hearing loss who resisted technology use were more likely to have hearing loss in the mild to moderate hearing loss range. These findings are consistent with previous research showing that children with normal hearing in one ear, or less severe hearing loss, were more likely to reject their amplification at some point (Fitzpatrick, et al., 2010; Walker, et al., 2013; Munoz, et al., 2014; Gustafson, et al., 2015). It was a surprise to see a high percentage of children with moderately severe hearing loss (41-70 dB HL) in the non-user category. It seems unlikely that such children could "pass" as hearing in a noisy school setting and it is concerning as it is well documented that children with moderately severe hearing loss are at high risk for language delays (Tomblin, et al., 2015). Preferred language was not reported as part of this survey. It is possible that children with hearing losses in the moderate to severe range were not benefitting as much from hearing aids and were more reliant on a visual communication system, such as Signed Exact English; or a visual language, such as American Sign Language.

For children with unilateral hearing loss, the most commonly reported grade for rejection of hearing aids was 5th grade, although resistance also peaked in preschool and 1st grade. Children with better hearing in the affected ear were more likely to become non-users of their technology, possibly because it is easier for those children to "get by" with the residual hearing they have; they have one normal ear, and enough hearing in their affected ear to be able to localize. For children with severe to profound unilateral hearing loss, poor family support was reported as the primary reason for non-use. It could be that parents (and/or children) did not feel that using a hearing aid in a severely to profoundly impaired ear was worth the effort, given the limited acoustic benefit.

For children with bilateral hearing loss, non-use was reported to occur most often in kindergarten, 3rd grade, 6th grade and 8th grade, with 6th grade being the most common grade overall for non-use. The peak in hearing aid non-use in kindergarten echoes findings of previous research showing that 5 to 6 year-old children were reported by parents to use their hearing aids less than full-time (Munoz, et al., 2013), This study also found that children entering middle school were likely to reject hearing technology, similar to research by Gustafson, et al. (2015) who found that children in grades 5-7 were less likely to wear their technology at school.

Unfortunately, the response rate for questions regarding grade at first resistance to hearing technology use was particularly low (only 26% for hearing aid non-use and 37% for FM/DM non-use), especially given that the overall response rate for his survey was quite high. In addition, very few teachers reported any information about high school age students; out of 135 students who rejected their hearing aids, 11 (8%) were reported to be in high school. Of interest, *all* 11 high school students who rejected technology were classified as hard of hearing (hearing loss in the mild, moderate, or moderately-severe range). It is possible that teachers did not feel that this question was particularly valuable or important; that they were unsure or had not kept track of the grade at which many of their students *first began* to reject their technology; that they simply could not remember the grades at which students first began to reject their technology; or (especially in the upper grades) that teachers had less regular contact with the students on their caseload. It would be challenging to document--or perhaps even *notice*--the initial stages of technology rejection; yet staying alert to the first signs of resistance is important in appropriate management of students who rely on such technology for educational access. Future research should focus on technology non-use in older children in particular, as this remains an underrepresented and less well understood group in the literature. In addition, it is important to develop a better understanding of students who are DHH as they move from high school to the job force or higher education—when individuals become responsible for their own technology and educational or vocational supports.

Different factors likely account for hearing aid non-use among younger children compared to teenagers. Kindergarten is the first time that children are away from care providers for a significant portion of their day; children who resist amplification in pre-kindergarten and kindergarten may do so because they were inconsistent users or not encouraged to use their hearing aids at home. In previous research, parents of younger children reported a need for more education and support from pediatric audiologists on the benefits of technology as well as strategies for hearing aid retention, especially for children with unilateral or mild losses (Moeller et al., 2009; Moeller, 2011; Munoz, et al., 2016). It could be that parental lack of understanding or difficulty getting toddlers to wear technology (Walker, et al., 2013) leads to inconsistent amplification usage in preschool age children; this survey did not query as to reasons for technology non-use by grade, so this remains speculative. Future research should seek to determine the relationships among early parent education, patterns of hearing aid use in the birth-to-three period, and consistency of hearing aid use in preschool and kindergarten.

As children move through school, peer approval becomes increasingly important. It may be helpful for students who are DHH to receive instruction and practice in how to talk about their hearing loss with peers and self-advocate; future research should aim to determine the benefits of such a practice. Teachers can discuss hearing loss with the class and practice strategies for being a good communicator. Perhaps it could be beneficial to provide opportunities for younger children who are deaf or hard of hearing to interact with other, including older, children who are deaf or hard of hearing. This might facilitate younger children developing a healthy identity and in feeling less stigmatized by their hearing loss. In addition, older children may be able to model pro-social, disclosure, and self-advocacy strategies for younger children.

Resistance to hearing aids peaks in early middle school when students are often mixed into a larger population, move between classes, and may become more sensitive to being different and fitting in. Prior to entering high school, hearing aid rejection peaks again. Teenagers may feel that hearing loss makes them stand out from their peers. All respondents in the current study reported social pressures as the main reason for technology non-use in the classroom, regardless of age. However, teenagers were particularly sensitive to social pressures, consistent with previous research on this population.

Based on this study, although non-use peaked in kindergarten and grade 3, 6th grade was when the greatest percentage of students began to reject personal hearing technology. It is important, then, to include explicit goals for consistent hearing aid use on a child's IEP or 504 Plan to achieve full time use during the early elementary years.

Classroom FM/DM non-use patterns

Participants reported that 1/3 of DHH students grades pre-K through 11th grade did not have classroom FM/DM recommended for their use. This survey did not provide information about who was responsible for fitting FM/DM, or why FM/DM was not recommended; there is no way to know from these data if these students were not candidates audiologically, if FM/DM was deemed educationally unnecessary, or if students expressed resistance or reluctance to FM/DM during the evaluation process. It is plausible that participants did not know if FM/DM had ever been recommended by a child's audiologist. It is also possible that children who use ASL to communicate would not be good candidates for FM/DM as spoken English used by classroom teachers could interfere with visual language used by a classroom interpreter. This is an area that has not been addressed in the literature, but would be useful in informing educational audiology practice. Of the students who *did* have classroom FM/DM recommended (and presumably included on their IEPs/504 plans), one third of those students did not use their FM/DM consistently. As communication mode/language of the children in this study was not reported, it is not possible to tease out these variables in this data set. This would be an important topic for future study.

Twenty percent of students who refused classroom FM/DM were students with unilateral hearing loss. This is especially troubling as these children are highly adversely affected by background noise in the classroom (Bess & Tharpe, 1984; Bess, Tharpe, & Gibler, 1986) and are at increased risk for language and academic delays (Lieu, 2004).

Children with mild, moderate, and severe losses made up an additional 55% of children who refused to use classroom FM/DM, with children in the mild range comprising 21% of non-users of classroom FM/DM. It is well understood that poor SNR (such as those found in typical classrooms) have a detrimental effect on speech perception for all children, but especially for children with permanent hearing loss (Shield & Dockrell, 2003; Jamieson et al. 2004; Blandy & Lutman, 2005). Research has also shown that "listening effort" increases at poor SNRs, and secondary task performance (note taking, for example) decreases (Howard, Munro & Plack, 2010).

Again, the most common reason cited for non-use of classroom FM/DM across grades was social pressure, and classroom FM/DM non-use peaked as children approached middle school (6th grade) and high school (9th grade). Educational audiologists and teachers of the deaf should consider strategies for increasing acceptance of and confidence about classroom FM/DM as children move through school, and work to establish these prior to students approaching their teens. Based on the participants in this study, one strategy to facilitate technology compliance might be contact with a peer group of students who are DHH. Nearly half of the non-users in this study were the "one and only" student with a hearing loss in their school. By contrast, only 8% of non-users came from programs where they interacted with other DHH students regularly. It is possible that students who had more contact with peers who were DHH were also students with more severe hearing losses (perhaps they were in self-contained, specialized classrooms for the DHH; perhaps they were receiving more pull-out services in groups with other DHH children), and were therefore more likely to wear their hearing aids more consistently. Nonetheless, this relationship is worth investigating further as, in this group of students, a very low percentage of DHH children who had regular peer contact resisted hearing technology use.

CONCLUSION

School plays an important role in ensuring that children with any type and degree of hearing loss use their personal hearing devices as well as classroom hearing assistive technologies consistently. Consistent hearing aid use in school can go a long way in optimizing communication and lifelong learning potential for all individuals with hearing loss. Results of this study suggest a need for better supports for children from preschool all the way through high school, with skills and attitudes in place prior to children approaching middle school as children appear to be at the highest risk for non-use of both personal and classroom hearing technology in 6th grade. Pediatric audiologists can assist schools by educating families early on about the importance of full time technology use in all settings, supporting families in enforcing consistent hearing aid use, and connecting families to other families who have children who use hearing aids to encourage communication with peers who are DHH. Educational audiologist, teachers of the deaf, and classroom teachers can collaborate in supporting children as they move through various stages of communication and social development; teachers might consider providing direct instruction in skills aimed at increasing self-confidence, resilience to peer pressure, and feelings of fitting in. Overall, results of this study suggest that interacting with other children who have hearing loss and use hearing technology may afford some protection against resistance to using technology. Schools should consider providing opportunities for children who are deaf or hard of hearing to interact regularly with peers who have hearing loss. This may reduce the stigma associated with using visible, wearable technology (both personal technology and classroom HAT), although more research is needed in this area.

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Appendix

Children Rejecting Hearing Devices Survey

Think about your caseload in 2015-2016 or, if you are already familiar, with your 2016-2017 caseload. Please answer the following based on what you know/recall about the students you serve. Best guesstimates are acceptable!

How many students were/are on your caseload?

Of those with bilateral loss with hearing aids recommended for both ears, how many students in your caseload (above) refuse to wear a hearing aid in one ear (wore one hearing aid 3x/month or less and usually wore the other aid)?
Of your caseload total (above), how many refused to use their hearing aids (wore 3x/month or less)?
Of your caseload total, how many occasionally use their hearing aids (1-2x/week)?
Of your caseload total, how many often use their hearing aids (3-4x/week)?
Of your caseload total, how many usually or always use their hearing aids (missed none or just an occasional school day, i.e., 3x per school year)?
Of your caseload total, how many did not have an FM/DM (classroom hearing technology) system recommended for their use?
Of your caseload total, how many refused to use recommended classroom hearing technology (wore 3x/month or less)?
Of your caseload total, how many occasionally use recommended classroom hearing technology (1-2x/week)?
Of your caseload total, if in secondary school, how many use classroom hearing technology only for certain classes (i.e., only English and Social Studies)?
Of your caseload total, how many often use recommended classroom hearing technology (3-4x/week)?
Of your caseload total, how many usually/always use recommended classroom hearing technology (missed none or just an occasional school day, i.e., 3x per school year)?

Think about your students who refuse to use their hearing aids or only use them occasionally (1-2x/week). Of these 'non-users' please answer the following about their degree/type of hearing loss to the best of your knowledge/ recollection. Again, your best guesstimates are acceptable.

How many have unilateral loss with mild to moderate loss in the poor hearing ear (26-70 dB)?
How many have unilateral loss with severe to profound loss in the poor hearing ear (71+ dB)?
How many have a high frequency loss (i.e. 'notch' at 3000 Hz - 8000 Hz) only?
Of those with bilateral loss and refuse to wear a hearing aid in one ear, what is the degree of loss in the ear that doesn't use the hearing aid? Please enter two numbers in the following box that represent (1) how many have mild-moderate loss? (2) how many have severe/profound loss? in the non-hearing-aid-use ear?
How many have mild loss (26-40 dB) of any type (sensorineural, mixed, conductive)? If the degree of hearing loss is different in the two ears, the better ear would have a mild loss.
How many have moderate loss (41-55 dB) of any type (sensorineural, mixed, conductive)? If the degree of hearing loss is different in the two ears, the better ear would have a moderate loss.
How many have moderate to severe loss (56-70 dB) of any type (sensorineural, mixed)? If the degree of hearing loss is different in the two ears, the better ear would have a moderate to severe loss.
How many have severe loss (71-90 dB) of any type (sensorineural, mixed)? If the degree of hearing loss is different in the two ears, the better ear would have a severe loss.
How many have profound loss (91+ dB) of any type (sensorineural, mixed, conductive)?

This time think about your students who refuse to use classroom hearing technology or only use it only occasionally (1-2x/week). Of these 'non-users' please answer the following about their degree/type of hearing loss to the best of your knowledge/ recollection.

How many have unilateral loss with mild to moderate loss in the poor hearing ear (26-70 dB)?
How many have unilateral loss with severe to profound loss in the poor hearing ear (71+ dB)?
How many have a high frequency loss (i.e. 'notch' at 3000 Hz - 8000 Hz) only?
How many have mild loss (26-40 dB) of any type (sensorineural, mixed, conductive)? If the degree of hearing loss is different in the two ears, the better ear would have a mild loss. 27 27/52 nonusers
How many have moderate loss (41-55 dB) of any type (sensorineural, mixed, conductive)? If the degree of hearing loss is different in the two ears, the better ear would have a moderate loss.
How many have moderate to severe loss (56-70 dB) of any type (sensorineural, mixed)? If the degree of hearing loss is different in the two ears, the better ear would have a moderate to severe loss.
How many have severe loss (71-90 dB) of any type (sensorineural, mixed)? If the degree of hearing loss is different in the two ears, the better ear would have a severe loss.
How many have profound loss (91+ dB) of any type (sensorineural, mixed)?

We now want to know about WHEN your students began to resist using their hearing aid(s). Please answer the following based on what you know/recall about the students you serve(d). Resisting hearing aid use means that they had been usually using their device(s) but then began to use them noticeably less time per week/month. If you have multiple students in any category below, please enter the grades that resistance began. For example, if you had 3 students with mild loss that resisted using their hearing aids you could enter (K, 3, 6) for the three grades during which their pattern of hearing aid use changed.

Unilateral loss with mild to moderate loss in the poor hearing ear (26-70 dB):
High frequency loss (i.e. 'notch' at 3000 Hz - 8000 Hz) only:
Mild loss (26-40 dB) of any type (sensorineural, mixed, conductive) in both ears or the better hearing ear:
Moderate loss (41-55 dB) of any type (sensorineural, mixed, conductive) in both ears or the better hearing ear:
Moderate to severe loss (56-70 dB) of any type (sensorineural, mixed) in both ears or the better hearing ear:
Severe loss (71-90 dB) of any type (sensorineural, mixed) in both ears or the better hearing ear:
Profound loss (91+ dB) of any type (sensorineural, mixed)?

We now want to know about WHY your students began to resist using their hearing aid(s). Please answer the following based on what you know/recall about the students you serve(d). Resisting hearing aid use means that they had been usually using their device(s) but then began to use them noticeably less time per week/month. Please enter numbers indicating the following: (1) malfunction/repair issues, (2) comfort complaints not related to malfunction (i.e., itchy, earmold feels tight...), (3) family pressures, (4) social pressures, (5) low functioning; haven't achieved successful wear as yet, (6) unknown - no good 'guess' about which of the other choices it would be. Example: You have two students with mild to moderate unilateral loss. One stopped using due to repair issues and the other due to social pressures. You would enter 1, 4 into the box.

Unilateral loss with mild to moderate loss in the poor hearing ear (26-70 dB):
Unilateral loss with severe to profound loss in the poor hearing ear (26-70 dB):
High frequency loss (i.e. 'notch' at 3000 Hz - 8000 Hz) only:
Mild loss (26-40 dB) of any type (sensorineural, mixed, conductive) in both ears or the better hearing ear:
Moderate loss (41-55 dB) of any type (sensorineural, mixed, conductive) in both ears or the better hearing ear:
Moderate to severe loss (56-70 dB) of any type (sensorineural, mixed) in both ears or the better hearing ear:
Severe loss (71-90 dB) of any type (sensorineural, mixed) in both ears or the better hearing ear:
Profound loss (91+ dB) of any type (sensorineural, mixed)?

We now want to know about WHEN your students began to resist using their classroom hearing technology (i.e., FM). Please answer the following based on what you know/recall about the students you serve(d). Resisting classroom hearing technology use means that they had been usually using their device(s) but then began to use them noticeably less time per week/month. If you have multiple students in any category below, please enter the grades that resistance began. For example, if you had 3 students with mild loss that resisted using their FM systems you could enter (K, 3, 6) for the three grades during which their pattern of hearing aid use changed.

Unilateral loss with mild to moderate loss in the poor hearing ear (26-70 dB):
Unilateral loss with severe to profound loss in the poor hearing ear (26-70 dB):
High frequency loss (i.e. 'notch' at 3000 Hz - 8000 Hz) only:
Mild loss (26-40 dB) of any type (sensorineural, mixed, conductive) in both ears or the better hearing ear:
Moderate loss (41-55 dB) of any type (sensorineural, mixed, conductive) in both ears or the better hearing ear:
Moderate to severe loss (56-70 dB) of any type (sensorineural, mixed) in both ears or the better hearing ear:
Severe loss (71-90 dB) of any type (sensorineural, mixed) in both ears or the better hearing ear:
Profound loss (91+ dB) of any type (sensorineural, mixed)?

We now want to know about WHY your students began to resist using their classroom hearing technology. Resisting classroom hearing technology use means that they had been usually using their device(s) but then began to use them noticeably less time per week/month. Please enter numbers: (1) malfunction/repair issues, (2) comfort complaints not related to malfunction (i.e., itchy, sounds funny...), (3) family pressures, (4) social pressures, (5) teacher resistance to using transmitter (appropriately), (6) low functioning; haven't achieved successful wear as yet, (7) unknown - no good 'guess' about which of the other choices it would be. Example: You have three students with moderate unilateral loss. One stopped using due to family pressure, one due to social pressure, and the last had a teacher who 'forgot' to use the transmitter frequently. You would enter 3, 4, 5 into the box.

Unilateral loss with mild to moderate loss in the poor hearing ear (26-70 dB):
Unilateral loss with severe to profound loss in the poor hearing ear (26-70 dB):
High frequency loss (i.e. 'notch' at 3000 Hz - 8000 Hz) only:
Mild loss (26-40 dB) of any type (sensorineural, mixed, conductive) in both ears or the better hearing ear:
Moderate loss (41-55 dB) of any type (sensorineural, mixed, conductive) in both ears or the better hearing ear:
Moderate to severe loss (56-70 dB) of any type (sensorineural, mixed) in both ears or the better hearing ear:
Severe loss (71-90 dB) of any type (sensorineural, mixed) in both ears or the better hearing ear:
Profound loss (91+ dB) of any type (sensorineural, mixed)?

Now think about those students who resist using hearing aids and/or classroom hearing technology due to social reasons. In other words, they were using their devices frequently and then their willingness to use them in school declined. Please enter the number of your students who use their devices 1-2 times per week or less per who interact with other students who have hearing loss as described below. Please select only once choice for each of your non-user students.

How many are 'one and onlies' with no other student in the school using hearing devices OR there may be another student or two with devices but this student does not really come into contact with the others AND it is unlikely that they come into contact with other students using hearing devices (i.e., not at all or no more than once per year)? **So, one and only with no real DHH contact.**
How many are 'one and onlies' with no other student in the school using hearing devices AND that they DO come into contact with other students using hearing devices (i.e., participates in get arranged togethers, chat groups, has DHH text friends, etc.)? **So, one and only but has some, perhaps regular, DHH contact.**
How many have at least one or two others at school that they see during the week (i.e., share SLP time together, in same class, etc**.). So, part of a small group of other students with hearing devices that they see often.**
How many are in a group of 4 or more students at school that they see every school day but are primarily in mainstream classes? **So, part of a group of students with hearing loss that come together daily** but spend much of the school day (i.e., 80%) in the mainstream with typically hearing peers.
How many are in a group of 4 or more students (i.e. center-based or cluster program) at school that they see every school day and may spend some of the time (i.e. 40%) in mainstream classes? So, **part of a group of students with hearing loss that spend much of the time together daily** as less in the mainstream with typically hearing peers.

Are loaner units available if a student experiences malfunction and needs to have the device sent in for repair? Please read all of the choices and choose only those that apply in your situation. You should have a choice for hearing aids and for classroom hearing technology (at least 2 responses).

Yes, a limited number of loaner hearing aids are available from school.
Yes, clinical audiologists in our area that our students often go to have loaner hearing aids available.
Yes, there is one or more clinical audiologists that offer loaner aids, but fewer than half of our students actually go to them or the families resist taking them there, making getting a loaner from the audiologist not a very functional choice for many students.
No, no loaner hearing aids are available from school.
Yes, we have enough 'extra' FMs and components that we can usually get a student 'up and running' within a day or two when their classroom hearing technology malfunctions.
Yes, we have some 'extra' FMs and components but the support services needed to get them to the student are limited, so it can often take a week or more to get the student 'up and running' again while the unit is sent in for repair.
We have some equipment but it is often dated, not the same, and/or inadequately suits the need of the student. So sometimes we can get the student 'up and running' again and other times the student goes without or ends up with loaner equipment that really isn't a good fit for his or her needs.
No, we really do not have loaner classroom hearing technology available for use when a student's unit malfunctions.

Thanks so much for your participation! Now tell us who you are:

Itinerant Teacher of the Deaf/Hard of Hearing
Center-based/resource room Teacher of the Deaf/Hard of Hearing
Educational Audiologist
Speech Language Pathologist working with DHH students
DHH Coordinator submitting group results

Hearing Aid Effect on Self and Peer Perception in Children With and Without Hearing Loss

Areeka Tiwari [1, 3]
Suzanne Miller [1, 3]
Yula Serpanos [2, 3]

[1] St. John's University, Queens, NY
[2] Adelphi University, Garden City, NY
[3] Long Island Doctor of Audiology Consortium

Corresponding Author:
Suzanne Miller, PhD, CCC-A
Department of Communication Sciences and Disorders
St. John's University
8000 Utopia Parkway
Queens, NY 11439
718-990-8020
Millers2@stjohns.edu

ABSTRACT

Purpose: **The perceived social stigma of wearing amplification (i.e., hearing aid effect) on self and peer perception in children with normal hearing (NH) from an urban public school and children with hearing loss (HL) from a school for the Deaf and hard of hearing was investigated.** *Method:* **Twenty-four children participated in the study. Twelve children with NH and 12 children with HL, fitted with amplification, were surveyed online. Participants were shown images of age-matched children fitted with amplification and asked to answer questions which targeted self and peer perception on items related to intelligence, social acceptance, and perceived differences from those pictured wearing behind-the-ear hearing aids or cochlear implants.** *Results:* **A Fisher's Exact Test revealed no significant differences in children with HL ($p>0.05$) on self-perception of intelligence or social acceptance of other children wearing amplification. Significant differences ($p<0.05$) were found in children with NH on items related to the social acceptance of and perceived differences from their peers fitted with amplification, suggesting the existence of the hearing aid effect in this group.** *Conclusions:* **The stigma of wearing amplification in children relative to differences in peer perception may exist among children with NH in an urban public-school setting.**

INTRODUCTION

Effects of wearing amplification not only influence the child with hearing loss (HL) but the children with whom they interact. Peers can make judgments, sometimes negative, about a child wearing amplification. Judgments are made in regards to appearance, personality, and intellect (Harter, 1998; Robins, Trzesniewski, Tracy, Gosling, & Potter, 2002). Negative judgments made by normal hearing (NH) peers can lead to diminished self-esteem and self-perception in the child with HL that wears amplification (Haley & Hood, 1986). Negative self-judgments can be based on the stigma of wearing hearing aids or from feeling different or inferior to children not wearing amplification.

The stigma associated with wearing hearing aids was termed the "hearing aid effect" by Blood, Blood, and Danhauer in 1977. The investigators reported that adults rating images of young children with and without hearing aids assigned negative attributes to the children depicted with hearing aids (Blood, Blood, & Danhauer, 1978). Since then, numerous studies confirmed the hearing aid effect in young to elderly adults that judged images of their peers, or other age groups ranging from children to adults and the elderly (e.g., Blood & Blood, 1982; Danhauer, Blood, Blood, & Gomez, 1980; Johnson & Danhauer, 1982; Johnson, Danhauer, & Edwards, 1982; Johnson, Danhauer, Gavin, Karns, Reith, & Lopez, 2005; Mulac, Danhauer, & Johnson, 1983). Later studies in adults suggested that the hearing aid effect had decreased, in part due to the technological advances in hearing instruments that created more cosmetically appealing amplification styles (e.g., Cienkowski & Pimentel, 2001; Rauterkaus & Palmer, 2014).

Research has also shown the hearing aid effect to be present in school-age children rating images of their peers wearing amplification. Dengerink and Porter (1984) surveyed students 10 to 12 years of age who judged images of five age-matched peers shown either wearing one of three different types of hearing aids (body aid, BTE, in-the-ear, eyeglasses) or without any devices. The children wearing hearing aids were rated significantly more negatively on intelligence, achievement, and personality than children not wearing any devices. The size of the hearing aid was found to be a factor in influencing perceptions; fewer negative ratings were observed with the smaller sized hearing aid. The authors concluded that in-service training should be provided to teachers as well as educational programs for student peers in the mainstreaming of children with HL (Dengerink & Porter, 1984).

Haley and Hood (1986) evaluated perceptions of 12 to 15-year-old adolescents with either NH or HL, from different school types (inner city, rural, suburban, school for the hearing impaired). The students rated videotapes of two age-matched peers speaking, one with NH and one with HL shown wearing a body aid, BTE, or no hearing aid. Support for the hearing aid effect was found in that the adolescents with and without HL rated the hearing-impaired peer more negatively on speech quality, intelligence, and willingness to interact socially with. However, students from the school for the hearing impaired were less critical when rating speech characteristics in the peer with HL. Two studies on indigenous Australian populations of children (5 to 12 years of age; Ryan, Johnson, Strange, & Yonovitz, 2006) and adolescents (12 to 18 years; Strange, Johnson, Ryan, & Yonovitz, 2008) rating images of peers wearing different hearing aid styles confirmed the presence of a strong hearing aid effect.

In contrast, Silverman and Largin (1993) did not find support for the hearing aid effect in elementary school-age children from a parochial school, who evaluated images of peers wearing hearing aids. It was surmised that the insular nature of the educational environment versus that of a public-school education might have fostered greater empathy and acceptance of those with disability.

The stigma associated with hearing aids may strain social interactions for children with HL. All children can experience low self-perception, but the contributing factors of self-perception are different for NH children than for children with HL (Eccles, Wigfield, Harold, & Blumenfeld, 1993). The child can experience lower self-esteem due to the differences in communication skills, social skills, and appearance after receiving a hearing aid or cochlear implant. Past research has demonstrated that Deaf children mainstreamed in hearing schools are more often overlooked for friendships (Stinson & Anita, 1999), and persons with visible disabilities, such as those with HL wearing aids, may have their abilities underestimated by their peers (Phemister & Crewe, 2004).

A child's perception plays a large role in his or her overall self-esteem (Haley & Hood, 1986). As children age, they begin to understand themselves and develop feelings about themselves. Increases in age can lead to more feedback and criticisms from parents, teachers and peers based on different sources such as academics and social skills (Eccles, et. al., 1993; Harter, 1993, 1998; Robins, et. al., 2002).

A goal of this investigation was to determine if there is a difference in self-perception between children without HL and those with HL fitted with amplification. The study also examined whether there is a difference in how children with NH or HL perceive their peers with HL, fitted with amplification. Based on these perceptions, this research sought to determine if the hearing aid effect, in terms of self and peer perception still exists, forty years later, in children with and without HL.

METHODS

A total of 24 adolescent children ages 9 to 18 years were included in this study. Twelve children with NH were recruited from the Queens, New York public-school system, and 12 children with HL, fitted with amplification were recruited from Mill Neck School for the Deaf, Mill Neck Center for Hearing Health, Mill Neck, New York, and the St. John's University Speech and Hearing Center. Of the children surveyed with HL, 6 wore BTE hearing aids and 6 used cochlear implants. The Institutional Review Boards at St. John's University, Queens, New York and Adelphi University, Garden City, New York approved this study.

All participants completed the same survey which was done online for convenience in data collection. Questions were developed by the researchers to target both self and peer perception on items related to intelligence, social acceptance (i.e., securing friendships and willingness to interact socially) and perceived differences from those pictured wearing behind-the-ear hearing aids or cochlear implants. Participants were initially asked their age, gender, and hearing status. They were then asked two survey questions aimed to understand self-perception. The self-perception questions focused on perception of intelligence (i.e., *Are you smart?*) and ability to secure friendships (i.e., *Do you make friends easily?*). Participants were then shown a collage of six images of children wearing either BTE hearing aids or cochlear implants. The images were grouped in a 3x2 table with the top three images showing the profile of two boys and one girl wearing cochlear implants. The bottom three images in the table showed the profile of two girls and one boy wearing visible BTE hearing aids. Survey participants were then asked four questions about the children pictured wearing hearing aids and cochlear implants. These questions were about perceived intelligence (i.e., *Are the kids in the pictures smart?*), willingness to secure friendships (i.e., *Would you be friends with any of the kids in the pictures?*) and to interact socially (i.e., *Would you hang out with the kids in the pictures?*), and perceived differences from (i.e., *Do you think the kids in the pictures are different than you?*) those pictured wearing visible hearing aids and cochlear implants. Survey participants answered 'yes', 'maybe' or 'no' to each question. A Fisher's Exact Test was performed to determine relationships in self and peer perception among children with NH and those with HL wearing amplification.

RESULTS

Table 1 presents the demographics of the participants by age, gender, hearing status, and amplification device.

Table 1. Demographic information for participants in the study; 12 children with normal hearing and 12 children with hearing loss.

a. Age Distribution

Age	*n*
9 to 12 years	9
13 to 15 years	8
16 to 18 years	7

b. Gender, Hearing Status, and Amplification Device

Hearing	Male *n*	Female *n*	Total *n*
Normal Hearing	7	5	12
Hearing Aid	2	4	6
Cochlear Implant	3	3	6

Table 2 presents the outcomes to the survey questions according to the NH and HL groups. No significant differences ($p > 0.05$) were found between the groups of children with NH and HL on the self-perception items on intelligence and ability to secure friendships. Peer perception outcomes showed some differences in the children with NH. The outcomes for the peer-perception question on willingness to secure friendships revealed that significantly more ($p = 0.04$) of the children with HL would seek friendships with other children with HL than would children with NH. Outcomes for the peer-perception question on perceived differences revealed that significantly more ($p = 0.04$) of the children with NH perceived children with HL as different from them as compared to the perceptions of the children with HL. No significant differences ($p > 0.05$) were found between the groups of children with NH and HL in the other peer-perception survey items on perceived intelligence or willingness to socialize with children with HL.

Table 2: Results from the survey on self and peer perception in 12 children with normal hearing and 12 children with hearing loss.

Survey Questions		Yes	Maybe	No
1. Are you smart?	NH	9	3	0
	HL	9	3	0
2. Do you make friends easily?	NH	6	6	0
	HL	7	5	0
3. Are the kids in the pictures smart?	NH	7	5	0
	HL	8	4	0
4. Would you be friends with any of the kids in the pictures?	NH	7	4	1
	HL	12	0	0
5. Would you hang out with the kids in the pictures?	NH	5	6	1
	HL	10	2	0
6. Do you think the kids in the pictures are different than you?	NH	2	3	7
	HL	0	0	12

DISCUSSION

Survey outcomes revealed no significant differences in terms of self-perception for survey participants with NH and participants wearing hearing aids or cochlear implants. Both groups considered themselves to be intelligent and sociable. These are positive findings for both groups of children during an important period of development.

There were also positive findings in terms of peer perception between the two groups for the question relating to intelligence. There was no significant difference in the judgement of children wearing hearing aids and cochlear implants as being intelligent, with both groups of children with NH and HL judging those pictured as "smart".

However, significant differences were found for two questions of peer perception. Normal-hearing children were less willing to seek friendships with the children pictured wearing BTE hearing aids or cochlear implants, and they were more likely to think those children were different from themselves. These findings, which exhibit the hearing aid effect, are similar to those reported decades earlier (Dengerink & Porter, 1984; Haley & Hood, 1986; Ryan et al., 2006; Strange et al., 2008) and suggest that the stigma of hearing aids and cochlear implants in children, relative to perceived differences and social interaction, may still continue to exist.

These findings have implications for the main-streaming of children with HL in an urban, pubic high school setting. Challenges could include discrimination or exclusion by normal-hearing peers. The negative reactions toward wearing amplification could affect childhood self-esteem during an important period of growth and self-awareness (Phemister & Crewe, 2004; Stinson & Anita, 1999).

To address these challenges, Ryan et al. (2006) developed an intervention segment on HL for children with NH. A 10-minute educational session was developed to inform study participants about the use and importance of amplification. Discussion points aimed to minimize the stigma of wearing amplification were also included. A booklet with images of hearing-impaired peers in various social situations was used for focus points and accompanied a discussion. This intervention was found to significantly reduce the negative perceptions associated with wearing hearing aids. Study results indicated there is the potential to change children's attitudes towards HL (Ryan et al., 2006). These findings are important because they indicated that greater awareness, counseling, and the mainstreaming of children with HL could help to normalize the appearance of wearing amplification and diminish the hearing aid effect in childhood and adolescence.

To help support mainstreamed children with HL, in-class information sessions about HL and hearing technologies should be developed. Informational counseling could help minimize the effects of the bias and ease the transition for teenagers with HL entering a mainstream public-school setting.

LIMITATIONS

The sample size of this study was small and may explain why these findings differ from past studies in adults, which indicate the hearing aid effect is decreasing (e.g., Cienkowski & Pimentel, 2001; Rauterkaus & Palmer, 2014). In addition, the data were collected from groups of students in two very different school settings. Had the children with HL wearing amplification been in the same classrooms as the public-school students surveyed, the results may have been different. However, despite these weaknesses, the results of this study are important. A hearing aid effect was found in an urban public-school setting. Informational sessions about hearing and hearing technologies could improve mainstreaming outcomes.

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The Effects of Background Noise and Personal MP3 Player Volume on the Audibility to Bystanders

Brian M. Kreisman, PhD[1]
Kate M. Longenbach, AuD[2]
Melina A. Blasi, AuD[3]
Brian J. Fligor, ScD[4]
Andrew B. John, PhD[5]

[1] Calvin University, Department of Speech Pathology and Audiology, Grand Rapids, MI
[2] Specialty Physician Associates, Bethlehem, PA
[3] Ear, Nose & Throat Associates, Baltimore, MD
[4] Lantos Technologies, Woburn, MA
[5] University of Oklahoma Health Sciences Center, Department of Communication Sciences and Disorders, Oklahoma City, OK

Corresponding Author:
Brian M. Kreisman
Department of Speech Pathology and Audiology
Calvin University
3201 Burton SE
Grand Rapids, MI 49546
Phone: (616) 526-7306
Email: bmk24@calvin.edu

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ABSTRACT

Purpose: **To determine whether overhearing someone's iPod is a valid way to tell whether the user was listening at hazardous listening levels.** *Method:* **An iPod Touch with standard earbuds was placed on a KEMAR mannequin in a sound booth. The output was recorded and measured from 28 inches away to simulate a bystander. Recordings of five songs at nine iPod volume levels were mixed with seven background noise conditions: quiet, pink noise (45, 60, and 75 dBA) and real-world noise (45 dBA speech babble; 60 dBA restaurant; and 75 dBA airplane). Participants were seated in the center of an eight-speaker array. The song was played at 0-degrees azimuth with the background noise presented from seven speakers (45, 90, 135, 180, 225, 270, and 315 degrees azimuth). Participants, 50 young, normal-hearing adults, indicated if they heard the music during each trial.** *Results:* **Participants were likely to overhear someone's iPod in quiet; however, the probability that the song was at a hazardous listening level was low. As background noise levels increased, participants' ability to overhear iPods decreased. Positive predictive value increased as real-world noise increased; however, the pink background noise did not maintain this trend.** *Conclusion:* **Overhearing someone's iPod does not necessarily indicate they are listening at a hazardous level, and not overhearing someone's iPod does not necessarily indicate they are listening at a safe volume level. Thus, being able to overhear music emanating from someone's earphones is not a good indicator that iPod user is damaging his or her hearing.**

Key Words: **iPod, personal audio systems, MP3 player, listening levels, recreational noise–induced hearing loss, noise exposure**

INTRODUCTION

Approximately 48 million Americans experience some degree of hearing loss (National Institute on Deafness and Other Communication Disorders [NIDCD]; 2017). While in many instances the cause of hearing loss cannot be prevented, a large percentage of Americans suffer from noise-induced hearing loss, a type of hearing loss that is nearly 100% avoidable (NIDCD, 2017).

Recreational noise can be generated by numerous sources. Recent media attention has been focused on personal listening devices as a potential source for noise-induced hearing loss. Although such devices have been around for many years, their popularity has increased with the release of MP3 devices such as Apple's iPod in 2001 and smart phones. With the ubiquity of iPods, pocket MP3 players, and MP3 integrated devices such as cell phones, Americans may be running a higher risk of potentially exposing themselves to harmful doses of noise on a daily basis. The National Institute for Occupational Health and Safety [NIOSH] (2018) defines hazardous levels at 85 dBA for an 8-hour time-weighted average and uses a 3-dB exchange rate (for every increase of 3-dB, the recommended exposure time is halved).

Recently, the World Health Organization (WHO) and International Telecommunications Union (ITU) published *Recommendation ITU-T H.870* (August, 2018), which is an international standard for MP3 player and earphone manufacturers (Rec. ITU-T H.870 (08/2018), 2018; Safe listening devices and systems: a WHO-ITU standard, 2019). This standard was developed with the input of clinicians, manufacturers, governments, and health communication professionals to regulate exposure to loud sounds through "personal audio systems" and to mitigate the hearing loss risk associated with their use. This standard recommends all MP3 players include noise dosimetry as part of the operating system, controls for volume limiting and parental notification, and personalized messages and cues to action. The adoption of this global standard by WHO and ITU suggests an international consensus that MP3 players pose a serious and specific threat to hearing, and technological interventions are required to mitigate the threat.

Personal Listening Devices

Numerous studies have examined the noise exposure and potential damage to hearing that may be caused by personal listening devices (e.g., Bradley & Fortnum, 1987; Catalano & Levin, 1985; Clark, 1990; Fligor & Cox, 2004; Keith, Michaud, & Chiu, 2008; Danhauer et al., 2009; Feder, Marro, Keith, & Michaud, 2013; Gopal, Mills, Phillips, & Nandy, 2018; Hellstrom, Axelsson, & Costa, 1998; Hodgetts, Riegler, & Szarko, 2007; Hoover & Krishnamurti, 2010; Kreisman, 2014; Portnuff, Fligor, & Arehart, 2013; Pugsley, Stuart, Kalinowski & Armson, 1993; Turunen-Rise, Flottorp & Tvete, 1991; Wong, Van Hasselt, Tang, & Yiu, 1990). In one such study, Gopal and colleagues (2018) examined temporary threshold shifts in participants with normal hearing after listening to 30 minutes of music through a personal audio system (iPod Touch). Testing included pure-tone thresholds from .5 to 12.5 kHz and distortion product otoacoustic emissions (DPOAEs), both pre- and post-exposure. Groups were assigned an iPod volume level of either 0% (no music), 50%, 75% or 100%. Results suggested a temporary threshold shift for the group that listened to the music at 100% volume for pure-tone octaves and interoctaves from 2-8 kHz. In addition, that group experienced a decrease in DPOAEs at 2 and 2.822 kHz when compared to the other groups. The authors concluded that, for a 30-minute listening period, setting the volume at a level of 75% or lower would be considered safe based on the conditions of the study, while listening at 100% would expose the listener to a potentially dangerous noise dose.

Only one investigation of the use of MP3 players in adolescents was found. Twardella and colleagues (2017) surveyed 2143 ninth-graders on their use of MP3 players, including listening duration and volume level, and compared their results to available hearing tests. Their results suggested that about 20% of the students listened at levels that may have exceeded the 85 dBA action level. These high-volume level listeners included more males and more students of lower socioeconomic status compared to other groups. Although 2.3% of children had indications of hearing loss, hearing loss was not associated with personal music player usage (Twardella et al., 2017).

Personal Listening Devices in Background Noise

Williams (2005) examined the volume levels and listening habits of personal stereo devices of passers-by in real-life settings and the durations at which individuals are listening. Personal stereo player levels were measured on a KEMAR manikin with an artificial ear simulator at two locations: near the subway station and outside of a town hall. Males had greater average noise exposure levels than females, although average participant exposure level was 79.8 dB (below the risk level of 85 dB). Williams (2005) concluded that use of personal stereo devices alone did not increase the risk for a noise-induced hearing loss.

Ahmed et al. (2007) examined the relationship between the use of portable audio devices and hearing health of university students. Most students who owned MP3 players used the devices frequently (5-7 days per week) but listened at a mid-level volume. Approximately 13% believed they had a hearing loss which could be noise related. Objective data revealed that output was lowest when the background noise condition was the lowest and increased with the level of background noise. Ahmed et al. (2007) concluded that most students were listening at safe levels.

Kreisman (2014) examined the sound level and duration of MP3 player use by college students in five locations on a college campus (fitness center, library, quad, busy crosswalk, and student union). Results suggested significant differences in MP3 output level between most locations. Overall, 25% of participants exceeded the NIOSH permissible occupational noise levels, based on the measure of MP3 free-field equivalent (FFE) sound pressure levels in dBA FFE and reported estimated hours per day of MP3 use. However, no significant differences were found for percentage of students exceeding the NIOSH noise dose between the five locations.

Overhearing Music from Another Listener's MP3 Player

Advice about the sound levels emanating from a listener's headphones is relatively widespread. For example, MedlinePlus patient instructions on the webpage "Hearing Loss and Music" stated, "If you wear headphones, the volume is too loud if a person standing near you can hear the music through your headphones" (https://medlineplus.gov/ency/patientinstructions/000495.htm). This advice has been repeated despite the dearth of evidence that it is accurate.

Keith et al. (2008) measured output levels of nine MP3 players and twenty-nine earphones, including earbud earphones, supra-aural earphones, and circumaural earphones. Maximum free-field equivalent (FFE) output levels were 83.4 to 107.3 dBA, and depended on MP3 player, earphone sensitivity, tightness-of-fit in the ear, and recorded level of the music. In light of lay reports of subjective judgements of music listening that is too loud, Keith and colleagues measured the sound level of music observed by a "bystander" at 0.25 meters (10 inches) by presenting music at 94 dBA in the ear canal. The authors concluded that it is unlikely that a bystander would accurately judge an MP3 user's listening level, but the factors influencing such observations vary widely (most significantly, the level of background noise in the environment).

Weiner, Kreisman, and Fligor (2009) studied whether overhearing music from another person's MP3 player headphones indicated that the output level was loud enough to potentially damage the MP3 listener's hearing. Thirty participants with normal hearing were seated in a sound treated room surrounded by four speakers at 45, 135, 225, and 315 degrees azimuth. A probe microphone was placed in the participants' ear canal to measure the output level from the MP3 player. Participants were asked to select a random song on their MP3 player and set the volume to zero. The MP3 player screen was then covered and participants instructed to "adjust the volume to where you like it." A single observer (Weiner) measured the output levels in the ear canal and then moved 26-inches away, to determine whether the music could be overheard. These measures were repeated four times in thirty second intervals in four levels of randomized background noise: Quiet (ambient noise of 34 dBA) and 45, 60 and 75 dBA of pink noise. Results showed an average increase of 13 dB when listening in background noise and 26% of participants listened at levels above 85 dBA FFE in the highest background noise condition. A significant correlation was found between audibility and set listening levels in background noise suggesting that if music was overheard in noisy environmental settings, it was more likely that the music was set at a high intensity level. The sensitivity and specificity of "If I can hear it, that means it's too loud" was assessed and it was found that, in the quiet condition, sensitivity was 100%. However, as background noise increased, sensitivity decreased and the number of false negatives increased. In general, this study found that if you can overhear a person's MP3 player, it does not necessarily mean they are listening at an unsafe level (Weiner et al., 2009). The major limitation of this study was that it used only one observer, who was moving between MP3 listening levels and judging whether the music was audible. The authors stated that "A thorough study of this topic would use enough observers to provide adequate power and foil trials would be randomly interspersed with test trials" (Weiner et al., 2009).

Purpose

If being able to overhear another's music from his or her earphones is an adequate screening measure to determine if music listening is "too loud" (presents a risk to hearing health) or not, then the WHO-ITU Safe Listening Devices and Systems recommendation is unnecessary. We sought to apply a level of scientific rigor to the question of whether or not overhearing another's music from his or her earphones is adequate to screen for unsafe listening behavior. With these considerations in mind, the purpose of the present study was to examine the relationship between overhearing music from another person's MP3 player and the volume of that person's listening level, specifically whether the level exceeds the auditory risk criteria of 85 dBA FFE. We designed this study as a more thorough follow-up to Weiner and colleagues (2009).

METHODS AND MATERIALS

Participants

Fifty adults, 20 males and 30 females, ages 20-28 years (M= 23.5 years, SD = 1.7) participated in this IRB-approved study. All participants passed a hearing screening that is described in the Procedures section. Participants received a $10 iTunes gift card for their time.

Stimuli

Music

Five top selling songs from iTunes for the week of June 14, 2009 were selected as the music stimuli. The songs included "Boom Boom Pow" by the Black Eyed Peas, "Fire Burning" by Sean Kingston, "I Gotta Feeling" by the Black Eyed Peas, "I Know You Want Me" by Pitbull, and "Love Game" by Lady Gaga. A ten second clip was sampled from the chorus of each song. The song clips were equalized for overall RMS amplitudes using Adobe Audition 1.5 and were imported into iTunes. Table 1 displays the overall RMS values before and after equalizing RMS for both tracks of each song, as well as the relative peak amplitude of each song after equalizing RMS. The equalized song clips were then imported onto an iPod Touch with standard iPod earbuds.

Table 1.

Starting RMS amplitude, equalized RMS amplitude, and peak amplitudes after equalization of the five music stimuli song clips, in dB relative amplitude, as measured in Adobe Audition 1.3 software.

Song	Starting Left Track RMS	Starting Right Track RMS	Equalized Left Track RMS	Equalized Right Track RMS	Equalized Left Track Peak dB	Equalized Right Track Peak dB
IGF	-14.38	-14.29	-15.64	-15.55	-1.42	-1.32
BBP	-15.10	-15.00	-15.64	-15.55	-0.69	-0.59
FB	-13.31	-13.22	-15.64	-15.55	-2.52	-2.43
LG	-15.35	-15.25	-15.64	-15.55	-0.48	-0.38
IK	-15.64	-15.55	-15.64	-15.55	-0.23	-0.13

Note: IGF = I Gotta Feeling, BBP = Boom Boom Pow, FB = Fire Burning, LG = Love Game, IK = I Know You Want Me.

Recording what would be overheard

All measurements were carried out in a double-walled, sound-treated booth. A KEMAR mannequin was placed in a chair in the center of the test suite. A DPA 4006-TL omnidirectional microphone was placed at a distance of 28 inches at 0-degrees azimuth from KEMAR's head in order to simulate approximate distance of an individual passing by someone listening to the iPod. A distance of 28 inches was chosen, rather than the 10 inches used in Keith et al. (2008), as this distance is roughly the distance of two people standing or sitting in proximity without invading one another's personal space. The microphone was coupled to a DigiDesign Digi002 rack, which served as the external interface/router for the ProTools 7.3 software on the Macbook laptop. The EarPod earbuds of the iPod were placed in the ears of the KEMAR mannequin in order to record each song clip to simulate a listener using their iPod with earbuds. This one earphone was chosen for use in this study, as the iPod EarPod earphone is the highest selling earphone, capturing 60% of global market share (Counterpoint Research, 2019).

All samples were recorded in a quiet condition (ambient background noise of 31.6 dBA). The iPod volume (iPV) icon has 16 dashes which range from 0% to 100% iPV in 6.25% increments. For the study, song clips were recorded at every second dash on the iPV (0, 12.5, 25, 37.5, 50, 62.5,75, 87.5, and 100 percent). The peak output levels in dBA for each iPV of each song clip were measured via an IVIE IE-35 real-time analyzer/sound level meter, with a Type-I microphone located next to the recording microphone (see Figure 1). At 100% iPV, peak levels at the recording microphone ranged from 56.2 to 59.2 dBA. After the song clips were recorded, a 0.1-second 440 Hz tone was added at the beginning and ending of each song clip to signal when each clip starts and stops as some of the clips were inaudible (e.g. clips recorded at 0% iPV).

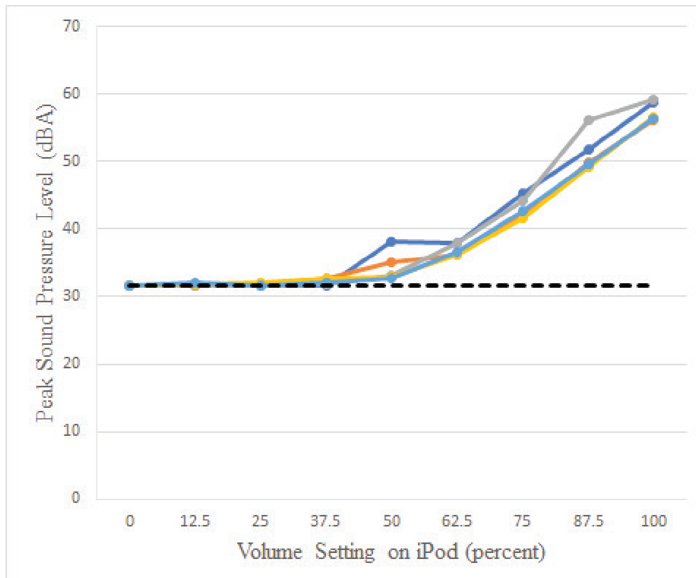


Figure 1. Peak Sound Pressure Level (in dBA) at the location of the observer of five songs at nine iPod volume settings (in percent). Note: Peak sound pressure level in dBA for five song clips playing through standard iPod earbuds on a KEMAR mannequin. Peak sound pressure levels were recorded in quiet at 2 feet four inches from KEMAR at 0 degrees azimuth to simulate the distance of a bystander. The dotted line represents the ambient background noise of 31.6 dBA.

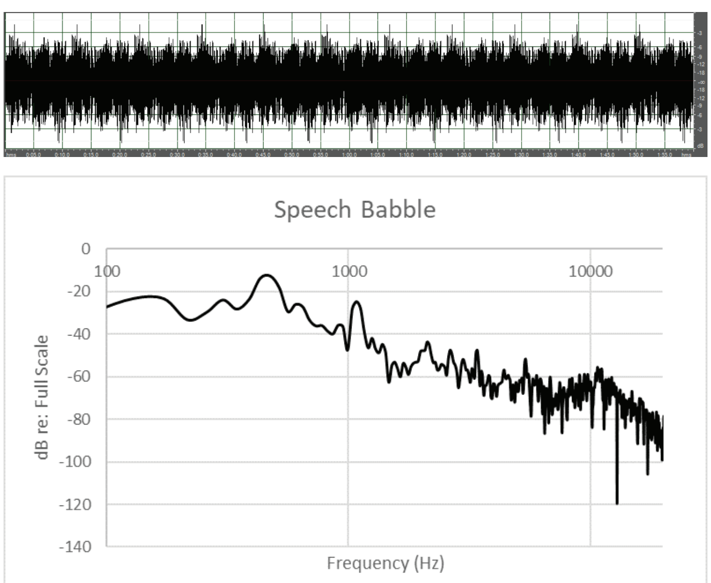
Background noise

The background conditions included quiet, three levels of pink noise (45 dBA, 60 dBA, and 75 dBA), and three levels of real-world background noise. These consisted of: 45 dBA speech babble copied from track 24 of the QuickSIN Speech-in-Noise version 1.3 CD (Etymotic Research Inc., 2006), concatenated to two minutes in length with no gaps in the signal; two minutes of 60 dBA restaurant noise from a recording at 44.1k Hz sampling rate inside a restaurant at lunchtime in downtown Boston, using a Shure SM58 microphone (Shure, Inc., Chicago IL) with XLR to USB adapter, recorded into Adobe Audition v1.5 software (Adobe Systems, San Jose, CA) in .wav file format; and two-minutes of 75 dBA airplane noise from a recording at 44.1k Hz sampling rate from inside of a flying Boeing 737 airplane using a Shure SM58 microphone with XLR to USB adapter, recorded into Adobe Audition v1.5 software in .wav file format. Two minutes of pink noise were generated using Adobe Audition v1.5 at -3 dB relative to full-scale.

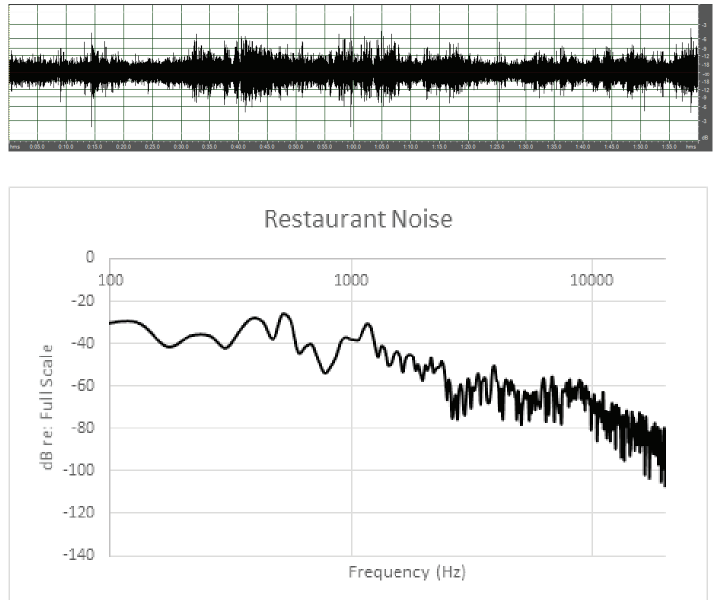
Pink noise was included as a background noise in the study as it is a non-kurtotic, gaussian noise, without peaks or gaps in the sound, as one would observe in real-world background noises; this ambient noise has also been used in several previous studies (Fligor & Ives, 2006; Weiner et al., 2009; Portnuff et al., 2013). Real-world background noise was included in this study to illustrate a few specific examples of a music-listener's environment. These real-world background noises should not be considered to generalize to all listening environments.

Speech-babble, restaurant noise, and airplane noise were equalized so that the highest peak in the signal was -3 dB relative to full-scale in Adobe Audition v1.5. Root-mean-square (RMS) level of speech-babble was 14 dB lower than the highest peak in the signal. Restaurant noise RMS level was 21 dB lower than the highest peak in the signal. Airplane noise RMS was 14 dB lower than the highest peak in the signal. Pink noise RMS level was 13 dB lower than the highest peak in the signal. Figures 2A, 2B, 2C, and 2D show the time-domain waveform and frequency response of each of the three real-world signals and pink noise.

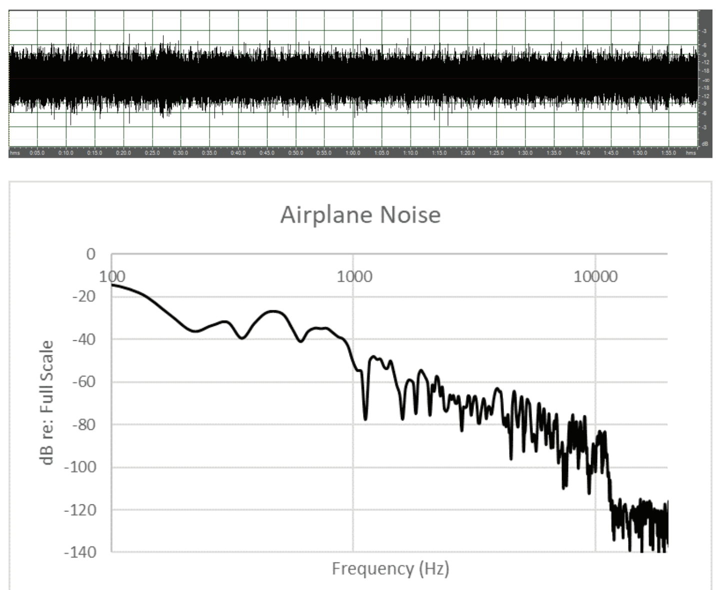
2A.



2B.



2C.



2D.

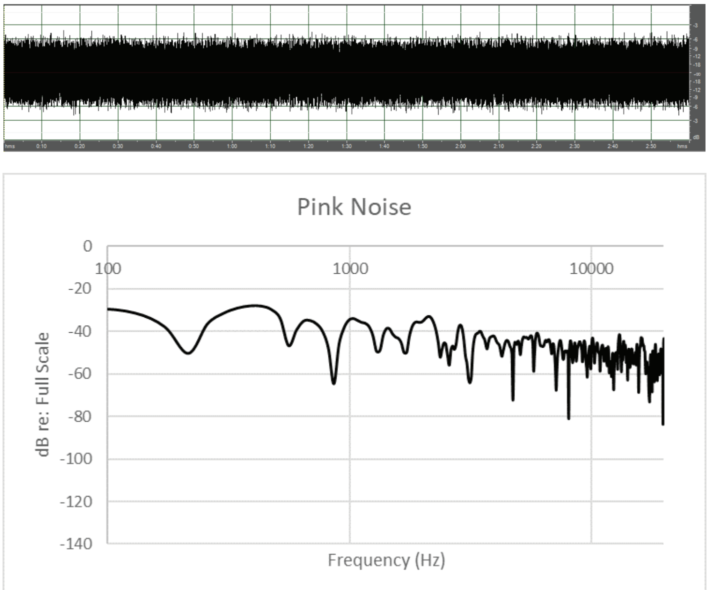


Figure 2. A. Time-domain waveform and frequency response of speech-babble signal. *B.* Time-domain waveform and frequency response of restaurant noise. *C.* Time-domain waveform and frequency response of airplane noise. *D*. Time-domain waveform and frequency response of pink noise.

Creating the final stimuli

Recordings were imported into separate tracks in ProTools 7.3 software, then sequenced to create the stimuli for each song, iPV, and background noise combination. The stimuli were routed from ProTools through a DigiDesign Digi002 rack to eight KRK Rokit Power 5 speakers. The speakers were arranged in an array 28 inches from the center of the participant's head at 0, 45, 90, 135, 180, 225, 270, 315 degrees azimuth. The song clip recordings were routed through the speaker at 0-degrees azimuth to simulate the sound coming from the iPod of a bystander, while the background noise was routed through the seven other speakers. Background noise levels were calibrated with an IVIE IE-35 real-time audio analyzer/Type-1 sound level meter placed in the center of the speaker array at the location of the listener's head.

Calculating FFE of the songs

Long-term average amplitude in dBA for each song clip at each iPV was measured in the ear canal of an investigator using an AudioScan Verifit system according to procedures described in ISO 11904-2 (2002), to determine sound levels at the iPod listener's eardrum. A probe tube was placed in the investigator's ear canal and a continuous sound level measurement was recorded for each song clip. Long-term average amplitude dBA of each clip was equated to FFE by subtracting out the eardrum transfer function in order compare the data to established damage-risk criteria (ISO 11904-1, 2002). Output at 100% iPV ranged from 91.6 to 95.8 dBA FFE. When presented at 100% iPV, all of the song clips had long-term average amplitudes greater than 85 dBA FFE, indicating potential risk for auditory damage. At 87.5% iPV, 4 out of the 5 song clips had long-term average amplitudes greater than or equal to 85 dBA. At 75% iPV and below, none of the song clips had average outputs greater than or equal to 85 dBA FFE. The means and standard deviations of the long-term average amplitude levels in dBA FFE are displayed in Figure 3.

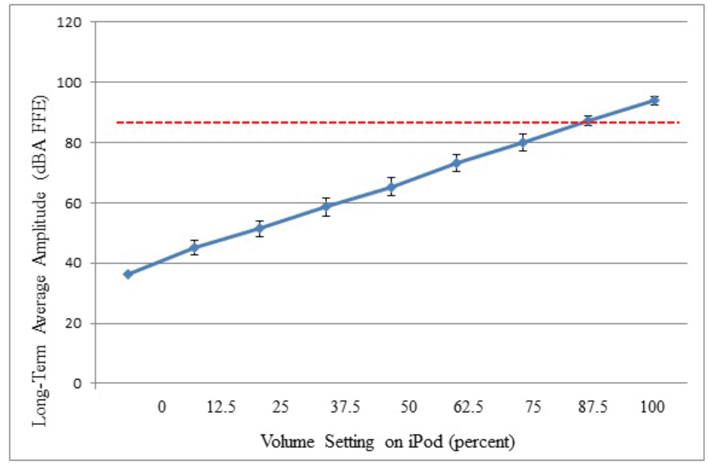


Figure 3. Means and standard deviations of long-term average amplitude levels in dBA FFE measures in the ear canal for five songs by volume setting. Blue diamonds indicate mean level for all songs at each volume setting. The dotted line at 85 dBA FFE indicates the hazardous listening levels.

Procedures

An audiologic screening was conducted on each of the participants to confirm normal hearing and normal middle ear function before participation in the study. An otoscopic examination was performed, followed by a bilateral tympanometry screening using a Madsen Otoflex 100 immittance bridge. A Type-A tympanogram (Jerger, 1970) was required. Pure tone air conduction testing was performed bilaterally using a pulsed 15 dB HL pure tone stimuli presented through a Grason-Stadler GSI 61 audiometer with E-A-R TONE 3A insert earphones. Thresholds were screened from 250 Hz through 8000 Hz including interoctaves. Following completion of the audiologic screening, the earphones were removed and the participant was seated in the center of the sound treated test suite. All participants passed the audiologic screening.

Written instructions were provided to the participant stating, "You will be listening to ten-second segments of noise and/or music. If at any time during the ten second segment, you hear the music, say 'yes.' The next sound clip will begin shortly thereafter. During some clips, you may not hear the music at all." After the participant indicated that he or she understood the instructions, the background noise levels were presented to the participant in order to familiarize the participant with the listening environment.

Due to the time required to complete testing, the testing was divided into two sessions lasting 60-90 minutes, with the first session being longer due to the hearing testing, and with a break in between the sessions. One session presented the clips in quiet and pink noise background noise, and the other session presented the clips in quiet and real-world background noise. The order of the test sessions was randomized for each participant. Within each session, the order of the clips was randomized for each participant, and each clip was presented once.

Results were analyzed via SPSS v. 17 using descriptive statistics. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated for each condition in order to determine whether audibility of the music over the background noise was indicative of hazardous listening levels. Receiver operating characteristic (ROC) curves were constructed for the two types of background noise (pink noise and real-world noise) to determine the optimal listening condition in which overhearing music from someone else's MP3 music is indicative that they are listening at hazardous levels.

RESULTS

Table 2 displays participant responses to each of the five song clips and each of the nine iPV settings for seven different background conditions. The number of participants who indicated the song clip was audible over the background noise are shown. We used a 50% criterion of the song clip being heard in a particular condition to be considered "audible." This 50% criterion was selected as the middle of a psychometric function. In the quiet background condition two of the five songs were audible at 25% iPV, and all songs were audible at 37.5% iPV and higher. In the 45 dBA pink noise background condition, one song was audible at 50% iPV and all songs were audible at and above 62.5% iPV. In contrast, in the 45dBA speech babble, one song was audible at 25% iPV, three songs at 37.5% iPV, and all songs at 50% iPV and higher. In the 60 dBA pink noise background condition, one song was audible at 75% iPV and all songs were audible at and above 87.5% iPV. In the 60 dBA restaurant noise condition, all songs were inaudible at and below 50% iPV, while all songs were audible at and above 62.5% iPV. In the 75 dBA pink noise background condition, none of the songs were audible regardless of iPV. In the 75 dBA airplane noise condition, one song was audible at 62.5% iPV and all songs were audible at and above 75% iPV.

Table 2.

Audibility Judgments of Song Clips Played on iPod at Nine Volume Settings in Quiet and Three Background Noise Levels with Pink Noise and Real-World Noise.

Noise Level	Noise Condition	Song	iPod Volume Level in Percent								
			0	12.5	25	37.5	50	62.5	75	87.5	100
Quiet	Quiet	1	1	6	22	92*	99*	97*	99*	100*	100*
		2	19	13	69*	95*	97*	97*	100*	100*	99*
		3	8	9	11	95*	99*	98*	99*	100*	99*
		4	6	14	51*	99*	96*	99*	100*	98*	97*
		5	10	13	43	97*	98*	97*	99*	100*	100*
45 dBA	Pink Noise	1	12	16	12	16	10	96*	94*	96*	96*
		2	10	8	8	18	46	94*	96*	100*	96*
		3	16	14	6	14	10	52*	96*	98*	100*
		4	10	10	8	6	86*	98*	100*	90*	98*
		5	6	6	12	6	20	96*	100*	98*	96*
	Speech Babble	1	4	2	0	32	96*	100*	100*	100*	100*
		2	0	28	88*	100*	100*	100*	100*	100*	100*
		3	6	6	2	32	98*	100*	100*	100*	100*
		4	0	0	4	72*	100*	100*	100*	100*	100*
		5	0	4	6	62*	98*	98*	100*	100*	100*
60 dBA	Pink Noise	1	18	10	12	10	20	12	16	80*	100*
		2	10	8	10	14	16	26	34	98*	98*
		3	16	18	6	8	18	20	6	54*	96*
		4	10	14	12	14	20	12	72*	94*	98*
		5	12	12	14	14	20	8	22	98*	96*
	Restaurant Noise	1	2	4	6	12	22	82*	100*	100*	100*
		2	6	6	10	14	44	98*	100*	100*	100*
		3	6	0	6	6	36	76*	100*	100*	100*
		4	4	4	8	8	42	90*	100*	100*	98*
		5	8	6	6	6	24	86*	100*	100*	100*
75 dBA	Pink Noise	1	4	6	10	10	0	8	4	10	8
		2	12	12	8	4	10	16	4	10	18
		3	16	4	12	6	6	6	14	4	4
		4	6	6	10	8	10	0	8	6	34
		5	6	8	2	16	10	2	12	8	2
	Airplane Noise	1	0	2	2	0	8	46	84*	100*	100*
		2	0	2	0	4	4	86*	100*	100*	100*
		3	0	2	6	0	4	22	98*	100*	100*
		4	2	0	2	2	2	42	100*	100*	100*
		5	6	2	6	0	0	48	100*	98*	100*

Note: The numbers are percent "yes" responses (n =100 for quiet condition; n = 50 for all other conditions). Asterisk (*) denotes song clip was audible during at least 50% of total trials in that condition.

In order to determine whether overhearing another person's iPod is a good predictor of whether he or she is listening at a hazardous level (a level equal to or above the 85 dBA FFE noise criteria), sensitivity, specificity, PPV, and NPV were calculated (see Table 3).

Table 3.

Sensitivity, Specificity, Positive Predictive Value (PPV), Negative Predictive Value (NPV) for Each Noise Condition

Condition	Sensitivity	Specificity	PPV	NPV
Quiet	.99	.35	.28	.99
45 dBA Pink Noise	.97	.61	.38	.99
45 dBA Speech Babble	1.0	.47	.32	1.0
60 dBA Pink Noise	.95	.83	.58	.99
60 dBA Restaurant Noise	1.0	.63	.40	1.0
75 dBA Pink Noise	.11	.92	.26	.81
75 dBA Airplane Noise	1.0	.75	.50	1.0

Note: Sensitivity, specificity, PPV, and NPV based on 85 dBA cut-off value. Values for the quiet condition were calculated across both testing sessions.

Recall that if being able to overhear another's music from his or her earphones is an adequate screening measure to determine if music listening is "too loud" (presents a risk to hearing health) or not, then the WHO-ITU Safe Listening Devices and Systems recommendation is unnecessary. Sensitivity measures the proportion of actual positives that are correctly identified (Parikh, Mathai, Parikh, Sekhar, & Thomas, 2008). For the purpose of this study, sensitivity is the percentage of people who indicated that they heard the song when the clip was actually playing at a long-term average amplitude level of 85 dBA FFE or louder. Sensitivity for songs played in ranged from .95 to 1.0 for all conditions except for the 75 dBA pink noise, in which sensitivity was only .11.

Specificity refers to the proportion of negatives that are correctly identified. In this study, this would be the percentage of people who did not indicate they heard the song when the clip was playing at a long-term average amplitude level below 85 dBA FFE. Specificity ranged from .35 in quiet to .92 in 75 dBA pink noise. In other words, songs playing at levels less than 85 dBA FFE were inaudible 92% of the time in the 75 dBA pink noise, while they were only inaudible 35% of the time in the quiet condition, indicating a high number of false positives (i.e., they heard the song even though it was below 85 dBA FFE).

Positive predictive value (PPV) uses both sensitivity and specificity and reflects the likelihood of a "disease" (here, a song clip playing with a long-term average amplitude level above 85 dBA FFE) when it is identified as being heard by the participants. Positive predictive value measures performance of a diagnostic method. For this study, PPV for the song clips being overheard by the observer show the probability that being able to overhear someone else's iPod is indicative of that person listening at hazardous level. Positive predictive value ranged from .26 in 75 dBA pink noise to .58 in the 60 dBA pink noise condition. In other words, even in the best condition, responses were only accurate 58% of the time. In general, PPV increased as background noise increased (except for the 75 dBA pink noise condition); however, PPV still remained poor. These results suggest that overhearing someone's iPod music is not a very accurate means of determining whether they are listening at a hazardous level.

Negative predictive value (NPV) shows the proportion of participants with a negative result who were correctly "diagnosed" (i.e., the proportion of participants who did not indicate that they heard the song when the clip was playing at a long-term average amplitude level below 85 dBA FFE) (Parikh et al., 2008). Negative predictive values ranged from .81 in 75 dBA pink noise to 1.0 in all three real world noise conditions. These scores indicated that when participants said they did not hear the clip in quiet, soft, or moderate pink noise or in the three real world background conditions, it was highly unlikely that the song clip had a long-term average amplitude level greater than or equal to 85 dBA. The NPV of .81 for the 75 dBA pink noise condition suggests that, compared to the other conditions, there is a greater likelihood that, although the song was not heard, it was being listened to at a hazardous level.

In order to determine the accuracy of a screening measure, a receiver operating characteristic (ROC curve) is constructed. The ROC curve provides a way to examine the accuracy of a diagnostic test and establish a threshold or cut-off for distinguishing between a positive or negative result (Rao, 2003). In our study, this test would be overhearing a song clip indicates a hazardous listening level.

Diagnostic tests typically involve a tradeoff between sensitivity and specificity (Rao, 2003). For example, if a threshold is set too low, results may show high sensitivity but low specificity, yielding many false positives. In our study, a false positive would be overhearing a song clip that has average amplitudes less than 85 dBA FFE criteria and therefore not a hazardous level. If a threshold is set too high, results may show high specificity but poor sensitivity. Rao (2003) reported that the best threshold or cutoff values have high sensitivity and low 1-specificity values. A low 1-specificity value indicates a low false positive (also known as false alarm) rate. When plotted on the ROC curve, this point will be located closest to the upper left corner of the graph. After all points are plotted, the area under the curve is examined. The larger the area, the more accurate the measurement tool is. A perfect measurement tool (100% sensitivity and specificity) would be located at the (0,1) intersection on the graph and have an area of 1.0 (Rao, 2003).

The ROC curves for pink noise and real-world noise are in displayed in Figure 4. The figure shows that test-performance was highest for the 60 dBA pink noise background condition, followed by the 75 dBA airplane noise for real world noise. In other words, overhearing music from someone's iPod in a 60 dBA pink noise background condition was the best predictor that the individual is listening at a level greater than or equal to 85 dBA. While the quiet condition has a high sensitivity value (99%), the specificity value was low (35%) indicating that when songs were played at levels less than 85 dBA, they were inaudible during fewer than half of the trials.

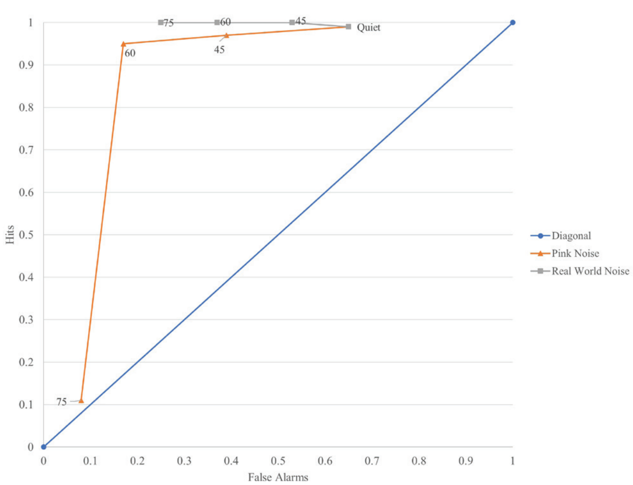


Figure 4. Receiver Operating Characteristic (ROC) curves for audibility of iPod playing at long-term average amplitude levels above 85 dBA FFE in different background noise conditions: Quiet (31.6 dBA of ambient noise), 45 dBA, 60 dBA, and 75 dBA of pink noise; and real-world noise of 45 dBA speech babble, 60 dBA restaurant noise, and 75 dBA airplane noise.

For pink noise, the thresholds or cutoffs increased as background noise levels increased from quiet to 45 dBA and 60 dBA of pink noise; however, when background noise increased to 75 dBA, the cutoff decreased significantly. Sensitivity was only .11 in this condition, while specificity was .92. These results indicated that the proportion of actual positives (song clips with long-term average amplitude levels greater than or equal to 85 dBA FFE) were only correctly identified (overheard by participants) 11% of the time. In contrast, for real world noise, sensitivity was near 100% for all conditions, while specificity decreased as background noise decreased.

Linear spectrum analyses of the 75 dBA pink noise and the five song clips were obtained in order to determine a probable cause for the lack of audibility of songs in that condition, in contrast to the airplane noise. It was determined that the song clips were completely masked by the noise. None of the song clips had peak sound pressure outputs above the energy in the 75 dBA pink noise and the signal to noise ratio was very poor. (see Figure 5).

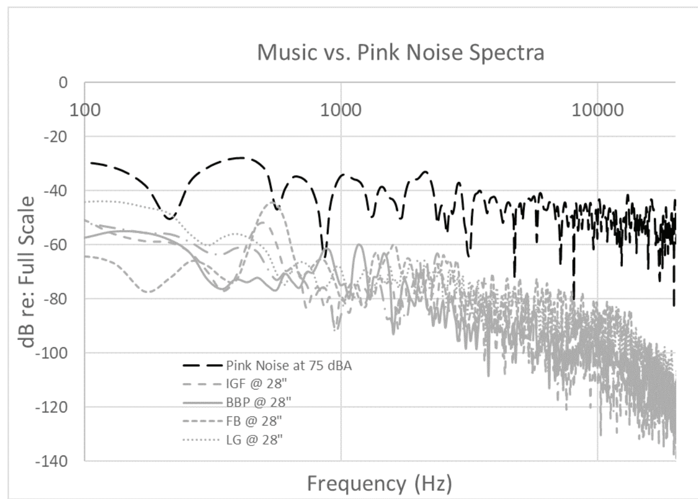


Figure 5. Frequency spectrum of pink noise at 75 dBA and frequency spectra of the five different songs based on sound level measured at 28 inches from the ear of the acoustical manikin. Note: IGF = I Gotta Feeling, BBP = Boom Boom Pow, FB = Fire Burning, LG = Love Game, IK = I Know You Want Me.

DISCUSSION

The purpose of this study was to rigorously apply test statistics to determine whether the ability to overhear another individual's iPod is indicative of a hazardous listening level for the iPod user that could potentially be harmful to hearing. The answer to the question "If I can overhear someone's iPod, does that mean they are listening at a hazardous listening level?" may not be a particularly clear cut one. Numerous factors influence audibility of an iPod including iPV, background noise, and song choice. Each of these factors must be taken into consideration.

Hazardous Listening Levels

When participants were listening for music clips in quiet, and in soft and moderate levels of pink background noise, clips playing at long-term average amplitude levels greater than or equal to 85 dBA FFE were audible more than half of the time to all participants. In a previous study by Weiner et al. (2009), when an observer was listening for music clips from an iPod in a quiet background condition and 45 dBA pink noise background condition, the majority of trials playing at or above the 85 dBA FFE level were also audible. Keith et al. (2008) predicted the same result, with 85 dBA FFE listening level being audible in 45 dBA of background noise. Weiner and colleagues found that in the 60 dBA pink background noise condition, a few trials where songs were playing at levels above 85 dBA FFE were inaudible to the observer. Findings from the current study also showed that during a few of the trials in the 60 dBA pink noise condition, not all participants overheard songs with long-term average amplitudes greater than or equal to 85 dBA FFE; however, the songs were audible to the majority of participants. Keith et al. (2008) predicted that bystanders on an idling city bus (60 dBA) would be able to hear higher frequency intermittent sound from earphones presenting music at 85 dBA FFE in the listener's ear.

Results from the current study revealed that when participants were listening for music in 75 dBA of pink background noise, none of the song clips were audible (in at least 50% of trials). Weiner et al. (2009) found that when an observer was listening for music stimuli in a 75 dBA pink noise background condition, some trials with long-term average amplitudes greater than 85 dBA FFE were audible to the observer. The audibility of certain clips was likely due to the fact that music stimuli levels were selected by participants and long-term average amplitudes for some songs exceeded levels of 100 dBA FFE. In comparison, the loudest song clips from the current study had maximum long-term average amplitude of 95.8 dBA FFE.

Volume Setting and Audibility

Peak sound pressure level (at the location of the observer) was measured for each song at iPV. Peak outputs varied from 31.6 dBA (background noise level) at 0% iPV to 59.2 dBA at 100% iPV. In the quiet background, no songs were audible at 0 and 12.5% iPV. Only two of the five songs were audible at 25% iPV, and all songs were audible at and above 37.5% iPV. These results suggest that songs are similarly but not equally audible across volume settings. Generally, audibility increased as iPV increased. Once audibility was achieved with a particular song in a particular condition, audibility was maintained with further increases in iPV.

These findings agree with previous findings from Weiner et al. (2009). Their results were that during all trials that were inaudible to the observer, music was playing at long-term average amplitude levels less than 85 dBA FFE. During trials where music was playing at levels greater than or equal to 85 dBA FFE, some song clips were audible to the observer while during other trials songs were not audible. Findings from the present study suggested that all songs at volume levels greater than or equal to 85 dBA FFE were audible to the majority of participants. Audibility of song clips played at volume levels less than 85 dBA FFE varied by the background noise condition. Findings from both studies demonstrated that audibility is not equal at all volume settings. These results are supported by the predictions of Keith et al. (2008), that audibility of the music to a bystander depended on the music being played (peaks relative to long-term average level), the level of the music, and the environmental noise level.

Background Noise

It is clear that the music was more audible in certain background conditions compared to the others. In the quiet background condition, participants overheard the song clips at low iPV (between 25% and 37.5%). These output levels were well below the 85 dBA FFE hazardous level. As background noise increased from 45 dBA to 60 dBA to 75 dBA, audibility of the songs decreased for both the pink noise and real-world noise. Audibility varied between pink noise and real-world noise at each background noise level. Compared to the pink noise, audibility for the real-world noise was achieved at a lower iPV. Recall that, in the loudest background condition of 75 dBA, no song was audible in the pink noise, while all songs were audible at and above 75% iPV in the airplane noise. This might suggest that environmental pink noise provided better test specificity (and better NPV) while the real-world background noises chosen in this study provided better test sensitivity (and better PPV).

When listening in a quiet, ambient environment, it is highly likely for one to overhear a nearby person's iPod, even if the person is not listening at a hazardous level. In the quiet condition, sensitivity was high; however, specificity was very poor due to the high number of false positives. In other words, it is common to overhear the music in a quiet setting even if the long-term average amplitude level of the song is below 85 dBA FFE, as indicated by the low PPV of .28 for this condition.

As background noise level increased, the PPV also increased, but not greatly. When music clips were presented 45 dBA pink noise background condition, PPV did increase in comparison to the quiet condition; however, PPV was only .38 for pink noise and .32 for speech babble. Positive predictive value was highest in the 60 dBA pink noise background condition. The PPV was .58, suggesting in this condition the test was accurate for overhearing songs with long-term average amplitude levels greater than or equal to 85 dBA FFE approximately 60% of the time. This finding suggests that if you overhear someone's iPod in a 60 dBA pink noise background condition, there is a higher probability that the person is listening at a hazardous level compared to overhearing the iPod in the two quieter background conditions. Comparatively, the PPV was lower at .40 in the 60 dBA restaurant noise condition. All song clips were inaudible in the 75 dBA pink noise background condition (using the 50% criterion), regardless of presentation level, and the PPV was only .26. Therefore, using this screening tool in the 75 dBA pink noise condition was practically useless, because even songs with long-term average amplitude levels greater than or equal to 85 dBA FFE were inaudible to the participants. In comparison, the PPV in the 75 dBA airplane noise was the .50, the second-highest in this study. Stated differently, in an airplane while 28 inches away, you could overhear someone's iPod with long-term average amplitude levels greater than or equal to 85 dBA half the time.

These findings are generally consistent with findings from Keith et al. (2008) and Weiner et al. (2009). That study determined that, as background noise increased, audibility of music to the observer decreased. Positive predictive value increased slightly and the number of false positives decreased as background noise increased. Weiner and colleagues also found that PPV was greatest in the 75 dBA pink noise background condition. In the current study, PPV generally increased as background level increased in both pink noise and real-world noise. The notable exception was when pink noise increased from 60 dBA to 75 dBA, the PPV decreased from .58 to .26. These results were likely due to the increased masking effects of the noise as pink noise exceeded even the highest peak sound pressure level by 15 dBA. The likely reason that our results differ from Weiner et al. is due to different methods; sound pressure of the music stimuli in Weiner et al. exceeded the song clips from our study by 5 dBA FFE or more. Data from our study suggests that audibility may increase as real-world background noise increases, which is similar to the trend that Weiner et al. found for pink noise. It should be stated that our findings are specific to the types of real-world noise in this study and caution should be used in generalizing the results.

Music Stimuli

It was determined that audibility varies slightly between songs. Even though songs were equalized for overall RMS amplitudes, there were still slight differences in their peak SPL. These differences caused some of the songs to be more audible than others in certain conditions. For example: 1) in the 45 dBA and 60 dBA pink noise conditions, song 4 was audible to participants at lower volume settings than the other songs; and 2) in the quiet condition, songs 2 and 4 were audible at 25 percent volume, while all other songs were inaudible at the same level.

Study Limitations

While this study was more rigorously designed than Weiner et al. (2009), a few limitations are worth noting. These include the choice of earphone, the distance of the listener, the hearing status of the overhearer, and the types of background noises evaluated. Caution should be used when generalizing our results. One limiting factor may have been that the study was carried out in a sound-treated test suite. Listener expectations within this synthetic listening environment may have contributed to a higher number of false positives in some of the conditions. The study only used ten-second samples of each song (a sample of the chorus) in order to save time and to reduce participant listening fatigue. There is a possibility that the selected ten-second clips did not capture the loudest peak SPL from the entire song, which could have potentially impacted results. Additionally, we only used one type of real-world background noise at each noise level. Results may vary with different types of real-world background noise. Finally, in order to control variability, we used only one type of earphone (the iPod EarPod). Therefore, results are limited to the EarPod and should not be generalized to other types of earphones or headphones, although we would expect most commercially-available earbud-style earphones to perform similarly.

Future Directions

While the current study used popular songs from iTunes as the music stimuli, it may be of interest to look at the audibility of songs from different genres of music; for instance, songs with higher peak-to-average sound levels would be more audible to a bystander, despite long term average levels being lower. In addition, the current study used an iPod Touch with standard iPod earbuds to assess audibility. In the future, it may be beneficial repeat this study with different styles of headphones, as some headphones attenuate background noise more than others (see, for example, Fligor & Ives, 2006; Keith et al., 2008). For example, if the earphone better seals the ear canal to attenuate background noise for the MP3 listener, less of the music sound may escape the ear canal. In such a case, a bystander may be prevented from overhearing the music even if it is being played at a hazardous level, thereby potentially changing the sensitivity and specificity.

Conclusion

The current study examined whether the ability to overhear someone else's iPod was indicative of that person listening at a hazardous level, or long-term average amplitude level greater than or equal to 85 dBA FFE. The results suggested that, in a quiet listening setting, it is highly likely that a nearby listener will overhear someone else's iPod; however, the chance that the person is listening at a hazardous level is only 28 percent, which is low. As background noise levels increase, the ability to overhear iPods generally decreases. Positive predictive value was higher in the louder conditions, indicating that if a person is able to overhear someone else's iPod in noisy listening setting, it is more likely that the person is listening at a long-term average amplitude level greater than or equal to 85 dBA FFE. In the 75 dBA pink noise condition, the noise completely masked all of the songs rendering them inaudible to the listeners regardless of the whether the levels exceeded 85 dBA FFE. It is necessary to keep in mind that the 85 dBA FFE noise exposure risk criterion is time-weighted. Therefore, individuals who are listening to music at long term average amplitude levels greater than or equal to 85 dBA FFE for long periods of time (8 hours or longer according to NIOSH standards) are at a greater risk for acquiring noise-induced hearing loss. Overall, these results suggest that whether or not a close bystander can overhear music from one's earphones is not a good screening measure for hearing loss risk. Technological interventions, such as those adopted by the WHO-ITU standard for safe listening devices and systems, are necessary to provide individuals with tools necessary to manage their risk for hearing loss from using MP3 players.

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Verification and Validation of Remote-Microphone Technology on Children and College-Age Adults who Have Autism Spectrum Disorder

Erin C. Schafer, PhD; Kamakshi V. Gopal, PhD; Lauren Mathews, MS; Kara Kaiser, MS; Emilee Canale, BS; Avery Creech, BS

Corresponding Author:
Erin C. Schafer
1155 Union Circle #305010
Denton, TX 76203-5017
Phone: 940-369-7433
Fax: 940-565-4058
Email: Erin.Schafer@unt.edu

ABSTRACT

Children and young adults who are diagnosed with autism spectrum disorder (ASD) often perform significantly poorer on speech recognition tasks in noise when compared to neurotypical peers due to abnormal auditory processing. Multiple studies support the use of open-ear remote-microphone (RM) technology to address the deleterious effects of noise. However, given the common sensory issues in this population, special considerations are necessary for an appropriate device fitting. As a result, the goal of this study was to examine data from a three-step, evidence based approach to RM system fitting, verification, and validation in 22 children and college-age adults who are high-functioning and have a diagnosis of ASD. During laboratory-based testing, the 22 participants completed the fitting and verification procedures while using non-occluding open-ear digital RM receiver. Twenty of the participants completed a 12-week trial period with the technology as well as pre-post speech-in-noise testing and questionnaires. Educational need for RM technology was documented with speech recognition and qualitative measures; these same measures validated the fitting following a trial period with RM technology. The real ear measures used to fit the RM technology confirmed that an appropriate fitting within approximately 5 dB of prescriptive targets is possible with the device used in this study. Overall, the three-step approach will provide the evidence necessary to gain access to RM technology in the schools for individuals with ASD, confirm an appropriate fitting, and validate the benefit of the device.

INTRODUCTION

Children and adults who have normal hearing sensitivity, but are diagnosed with autism spectrum disorder (ASD) demonstrate abnormal processing of complex sensory stimuli in multiple domains including auditory, visual, tactile, smell, and taste (Tomcheck & Dunn, 2007; Ashburner, Rodger, & Ziviani, 2008). Auditory-specific processing issues experienced by 70-100% of individuals with ASD include filtering (underresponsiveness and overresponsiveness), attention, distractibility, responding, and poorer speech recognition in noise as compared to neurotypical peers (Alcántara, Weisblatt, Moore, & Bolton, 2004; Ashburner et al., 2008; Rance, Chisari, Saunders, Rault, 2017; Rance, Saunders, Carew, Johansson, & Tan, 2014; Schafer et al,, 2013; Tomcheck & Dunn, 2007). Temple Grandin (1992), an adult who has ASD and is an advocate for ASD communities, summarizes her processing difficulties (1992): "My hearing is like having a hearing aid with the volume control stuck on 'super loud'. It's like an open microphone that picks up everything. I have two choices: turn the mike on and get deluged by sound, or shut it off."

Although few clinical audiologists are currently fitting hearing technology on individuals with ASD, open-ear remote-microphone (RM) technology that is designed for individuals with normal hearing has the potential to greatly improve auditory function in this population. Multiple studies suggest that, in children with ASD, use of RM technology at home, school, and in everyday situations significantly improves speech recognition in noise, auditory comprehension, on-task behaviors in the classroom, parent-rated auditory function, physiologic stress levels, and self-perceived listening abilities (Rance et al., 2014, 2017; Schafer et al., 2013, 2014b, 2014c, 2016, 2019). In addition, individuals with ASD that underwent intense auditory training and used RM technology for 12 weeks showed significant changes in auditory behavioral performance and in auditory electrophysiological responses (Schafer et al., 2018; Gopal et al., 2019).

Rationale

Given the specific auditory needs and tactile sensitivities in many people who have ASD, appropriate methods for fitting and validation are critical to ensure an individualized RM-technology fitting and to document benefit from the device. In particular, we propose a three-step, evidence-based approach that can be used to (1) document educational need for RM technology, which will be required to include this assistive technology in a child's Individualized Education Program at school (IEP; Individuals With Disabilities Education Act, 2004), (2) refine the RM technology fitting and verification procedures for children with ASD as compared to a previous investigation (Schafer et al., 2014a) and (3) examine multiple strategies that may be used to validate individual benefit from the device.

METHODS

Participants

Study participants included 22 children and college-age adults, ages 7-21 years old (M =14;9 years; SD =5;3), with a formal diagnosis of ASD per parent report. Additional information about the participants is provided in Table 1. Participants had normal air conduction hearing thresholds of at least 15 dB HL in each ear from 250 to 8000 Hz. A hearing screening was conducted rather than obtaining traditional hearing thresholds due to the levels of cooperation of the participants. Participants were recruited by distributing flyers to clinics within the community.

Table 1. Demographic Information about Participants

Participant	Age	Sex	Other Disabilities
1	9;6	F	ADHD, APD
2	21;8	F	ADHD, anxiety disorder
3	21;9	M	ADHD
4	21;5	F	ADHD
5	7;11	M	ADHD, language disorder, anxiety disorder
6	16;8	M	ADHD, learning disorder
7	10;3	M	None reported
8	12;0	F	SLI, language disorder
9	20;8	M	Suspected syndrome
10	20;6	M	ADHD, APD, learning disorder
11	16;4	F	anxiety disorder
12	10;2	M	None reported
13	23;5	F	ADHD, depression, anxiety disorder
14	9;5	M	None reported
15	15;5	M	None reported
16	8;10	M	ADHD, language disorder, apraxia, APD
17	15;2	M	Language disorder, learning disorder
18	10;11	F	ADHD, anxiety disorder
19	10;11	M	APD
20	9;1	F	language disorder
21	17;2	F	ADHD, language disorder, anxiety disorder
22	15;11	M	ADHD, language disorder, anxiety disorder

Note. ADHD=attention-deficit hyperactivity disorder; APD=auditory processing disorder. For this study, adult performance is defined as ≥ 14 years.

Equipment

Each participant was fit with bilateral Phonak Roger Focus receivers, size 0 to 2 slim tube, and small domes. The receivers were synched to a Roger Pen transmitter. Adjustments to the receiver volume were made with a Phonak Roger inspiro transmitter, which was synched to the receivers when adjustments to receiver volume were necessary. To verify that the fitting was appropriate for the participants, real-ear to coupler difference and speech-mapping was conducted on each ear using the Audioscan Verifit 2 as measures of verification.

Procedures

This study was approved by the University of North Texas Institutional Review Board. Before testing ensued, an informed consent form was signed by the parent or participant as well as a child assent form for participants less than 18-years-old. Participants were required to pass the hearing screening as well as a non-verbal intelligence test (i.e., IQ of > 70).

Determining Educational Need

Following the three-step approach proposed in the rationale, the first step was to determine educational need for hearing technology with behavioral and qualitative measures that were feasible to administer in an audiology clinical or educational setting. Behavioral speech-in-noise thresholds were assessed in cooperative participants using the recorded version of the Bamford-Kowal-Bench Speech-in-Noise (BKB-SIN) test (2005) calibrated to 60 dBA. This test estimates a person's speech-in-noise threshold at the 50% correct level. Participants also completed the student version of the Listening Inventory for Education – Revised Student Appraisal (Student L.I.F.E.; Anderson, Smaldino, & Spangler, 2011), where participants rate their classroom listening abilities as compared to peers on a scale of 5 (always easy) to 1 (always difficult). Parents of children less than 14 years of age and participants greater than 14 years of age were asked to complete the auditory subtest of the Child Sensory Profile 2 (Dunn, 2014) and the entire Adolescent/Adult Sensory Profile (Brown & Dunn, 2002), respectively. Parents or older participants who were not accompanied by a parent were asked to complete a case history form, which included a checklist (Table 2) of reported listening difficulties (Schafer et al., 2019). The use of multiple measures offers multiple assessments to examine potential listening difficulties in various situations.

Table 2. Parent- or Participant-Reported Listening Difficulties

Difficult Listening Situation	Participant Number
In most situations	1,2,4,8,10,13,15,19,20,21,22
In small groups	8,10,13
In large groups	2,5,7,9,10,11,13,14,16
In the classroom	2,5,7,8,9,10,13,14
At parties	2,4,5,9,10,11,13,14
In restaurants	2,5,8,9,10,13,14
In other social situations	2,4,10,11,13,14,16
Listening Problems	
Paying attention	1,2,3,4,5,7,8,9,12,13,14,15,18,20,22
Confused in noisy situations	1,2,5,7,8,9,11,14,15,16,17,18,19,21
Sensitive to loud sounds	1,2,3,4,5,6,7,8,9,11,15,16,17,19,20,21,22
Difficulty sitting still	2,4,5,9,10,11,15,20,22
Often daydreams	1,2,3,4,8,10,11,12,13,14,15,18,20,22
Prefers to play/do activities alone	2,4,8,9,11,14,15,16,19,21
Shy and anxious	2,7,8,10,13,15,16,18,20.22
Does not complete assignments	1,2,8,9,14,18,20,22
Easily distracted	1,2,3,4,5,7,8,9,11,12,13,14,15,18,20,22
Difficulty following directions	1,4,7,8,9,10,13,14,15,18,19,20,21,22
Easily upset by new situations	1,2,4,6,8,10,15,16
Impulsive	2,3,5,6,9,10,11,15,20,22
Often asks for repetition	1,2,4,7,8,10,14,15,20,22
Yelling or rowdy behavior	7,10,20,22
Lacks self confidence	2,4,6,8,10,11,12,13,15,16,17
Easily frustrated	1,2,3,4,5,6,7,8,9,10,11,14,15,16,17,18,19

Fitting and Verifying the RM Technology

The second step was to obtain two real-ear measurements that we propose when fitting the Roger Focus receiver to individuals diagnosed with ASD. All 22 participants (43 ears) completed the fitting and real-ear verification portions of the investigation during the initial testing session. One participant would only tolerate the real-ear measures on one ear. The primary goals of the fitting with the Audioscan Verifit 2 were to (1) individualize the fitting by adjusting for the real-ear-to-coupler difference (RECD) and (2) ensure that the output from the receiver, as measured in the ear, met the Desired Sensation Level (DSL) v5 prescriptive targets (2005). To begin real-ear measurements, "Speech-map" was chosen from the given list provided on the Audioscan Verifit 2. Measurements were obtained using DSL v5 - Child targets and inserts + foam for the HL transducer. "On-ear" was selected as the mode, and "FM" was selected as the instrument. The participant's chronological age was selected, and flat 15 dB HL hearing thresholds from the hearing screening were entered for both ears. After insertion of the probe-tube into the ear canal and coupling of the RECD transducer to the foam eartip, the real-ear response curve and RECD were obtained for both ears, as tolerated.

Following the RECD measurement, "on-ear" was selected for the mode, and "FM" was selected for the instrument. The first measurement was obtained by inserting the probe microphone into the participant's ear. The FM receiver was, then, placed on the ear, and the Roger Pen was placed inside the sound chamber with the receiver microphones facing the reference microphone. A real-speech input, which is appropriate for a chest-level transmitter microphone (i.e., 84-dB sound pressure level [SPL]), was used to measure the output of both receivers at 1000, 2000, 3000, and 4000 Hz. If the average DSL targets at 1000, 2000, 3000, and 4000 Hz were not met within 2 dB, the volume of the receivers was adjusted using the inspiro transmitter, and the receivers was, then, re-synched to the Roger Pen. This procedure was replicated until the average output was as close as possible to the targets at 1000, 2000, 3000, and 4000 Hz. It is important to note that frequency-specific adjustments are not possible on the Roger Focus, so the final volume level that was used for the study was the level that resulted in the smallest difference between the targets and measured output.

In contrast to a previous study on children with ASD (Schafer et al., 2014a), RECD was measured in the present study. Also, in the present study, maximum power output (MPO) was not measured because results of the previous study showed (1) that the MPO with a similar receiver never exceeded and was often substantially lower than the children's estimated uncomfortable loudness level, and (2) that the children reported the settings determined via real ear measures to be comfortable when listening to speech in the presence of background noise according to loudness ratings. In addition, the maximum output value of the Roger Focus receiver coupled to the SlimTubes is a conservative 80 dBA free field equivalent.

Validation Measures

All participants were asked to use the system at home and at school during a 12-week trial period. After the trial, the L.I.F.E questionnaire was repeated, and cooperative participants were asked to complete percent correct speech recognition in noise with and without the RM technology using fixed-intensity stimuli from the BKB-SIN. The examiner presented the monitored live-voice speech stimuli at 65 dBA from a head-level loudspeaker located 0 degrees azimuth in the soundbooth, and the associated noise from the compact disc was presented at 70 dBA from a head-level loudspeaker located at 180 degrees azimuth (-5 dB signal-to-noise ratio [SNR]). A challenging SNR was used to simulate listening in a noisy classroom (Knecht et al, 2002; Cruckley et al, 2011). In the RM technology condition, the examiner wore the talk-over microphone and the transmitter microphone (6 in from mouth). In addition, after the trial period, the L.I.F.E. and Sensory Profile questionnaires were repeated.

RESULTS

Documented Educational Need

A summary of the performance on the behavioral and qualitative test measures is provided in Table 2. All participants showed listening difficulties on at least one measure, and all but two showed difficulty on two measures. Eleven of the participants showed poorer-than-expected performance on three or four of the measures.

Table 3. Performance Across Measures to Assess Educational Need

Participant	BKB-SIN	Student L.I.F.E.	Sensory Profile	Difficulty Checklist
1	–	–	–	–
2	–		–	+
3	+	+	+	–
4	–	+	–	–
5	–	–	+	–
6	–	–		+
7	–	–	–	–
8	–	–	–	–
9	+	–	–	–
10	+	–	–	–
11	–	–	–	–
12	+		–	+
13	+		–	–
14	+	–	–	–
15	–		+	–
16	–	–	+	–
17	–		–	+
18	+		–	–
19	+	–	–	+
20	+	–	+	–
21	–	–	–	+
22		–	+	–
Average	0.73	45.8	25.6	10.4 problems
SD	2.6	13.7	5.7	3.8

Note. + = normal or better-than-expected performance using test manual; – and shaded = worse-than-expected performance. Lower performance on the L.I.F.E. was defined as at least some listening challenges. Lower performance on the Child Sensory Profile 2 questionnaire was defined as at least one SD below the mean raw score; on the Adult/ Adolescent Sensory Profile, at least two of four abnormal quadrants (i.e., rating of more or much more than most people). On the parent/participant checklist poor performance was defined as reported listening problems in at least one-third (8/23) checklist items (Table 2). Empty cells indicate missing data.

Verification of RM Technology

All 22 participants (43 ears) completed RECD and real ear measures to attempt to meet DSL targets. As shown in Figure 1, the examiners were able to meet the target within a few dB with the greatest difference at 2000 Hz.

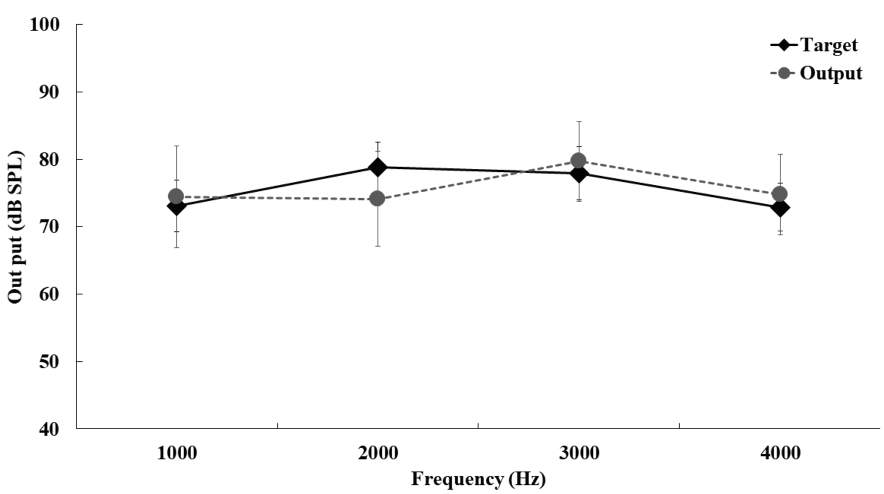

Figure 1. Average Desired Sensation Level prescriptive target and measured output from the RM technology.

To determine if there was a significant average difference between the targets and the output (condition), a two-factor repeated measures analysis of variance (RM ANOVA) was conducted. The analysis revealed no main effect of condition (F [1, 344] = .01, p = .94), but a significant main effect of frequency (F [3, 344] = 75.1, $p < .0001$) as well as an interaction effect between condition and frequency (F [3, 344] = 32.0, $p < .0001$). Post-hoc analyses of the main effect of frequency with the Tukey Kramer Multiple Comparisons Test suggested that all frequencies resulted in different output with the exception of 1000 and 4000 Hz. The post-hoc analysis on the interaction effect yielded no significant average difference between target and output for 1000 Hz ($p > .05$) but significant average differences for 2000 Hz (4.8 dB), 3000 Hz (1.9 dB), and 4000 Hz (1.8 dB) ($p < .05$). Despite the average differences, the Speech Intelligibility Index for average speech is at or above 94% for every ear.

Validation

Twenty of the 22 participants completed the trial period, and with the exception of one participant, completed at least two post-trial measures: percent correct speech recognition in noise, the student L.I.F.E., and the Sensory Profile (Table 4).

Table 4. Post-Trial Performance Changes Across Measures

Participant	BKB-SIN	Student L.I.F.E.	Sensory Profile
1	+	+	+
2	+		+
3	+	–	
4	–	–	
5	+	+	–
7	+	+	+
8	+	+	–
9	+	–	
11		–	+
12	–		+
13	+		
14	–	+	+
15	–		–
16	+	–	–
17	+		
18	+		+
19	–	–	+
20	+	+	–
21	+	+	+
22	+	–	

Note. + and shaded = improvement relative to initial measurement; – = no improvement. Notable changes include at least 10% improvement on the BKB-SIN, at least 8 scale scores on the L.I.F.E., and a change of at least one rating category on the Sensory Profile. Empty cells indicate missing data due to lack of cooperation.

Nineteen of the 22 participants were able to complete the speech recognition in noise testing with and without the RM technology. As shown in Figure 2, the average performance improved by 29%, and according to a one-factor RM ANOVA, this improvement was significant (F [1, 38] = 22.4, p < .001). When examining the individual data, 14 of the 19 participants experienced improvements ranging from 10% to 80% with the remaining participants showing limited or no improvement.

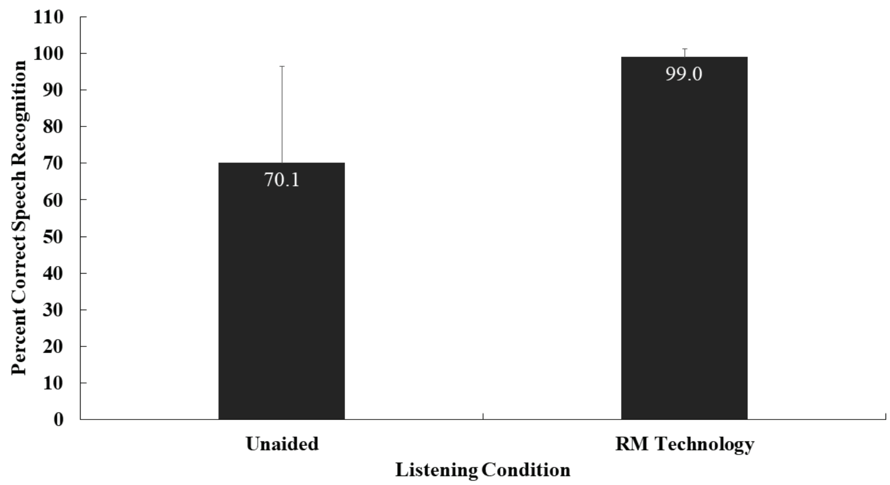

Figure 2. Average speech recognition performance in noise with and without RM technology.

Fourteen participants completed the post-trial L.I.F.E. with reported improvements by seven. On average, the rating changes were significant (F [1, 28] = 5.0, p = .04). Fourteen participants completed the Sensory Profile with improved ratings reported by nine individuals. Raw scores on the auditory processing section may be calculated on the Child Sensory Profile 2 (Pre-trial Mean=25.6, SD=5.7; Post-trial Mean=20.9, SD=5.8); on average, the rating changes for the 11 children were significantly better (F [1, 22] = 13.4, p = .004). When examining improvements across the measures, all but one participant improved on one measure and nine participants improved on one or more measures.

DISCUSSION & CONCLUSIONS

This study provided evidence to support the use of a three-step approach to (1) document educational need, (2) fit and verify RM technology in children and college-age adults with ASD, and (3) validate that the device provides benefit. The speech recognition and qualitative measures were able to document expected listening difficulties and educational need for RM technology in the classroom (Table 4). This evidence could easily be collected from a clinical or educational audiologist. Prior to the trial period, RM technology was fit using an objective approach that adjusts for ear canal volume and ensures appropriate output for conversational speech. Although the output of specific frequencies could not be adjusted, overall, the fittings met target within 5 dB SPL, on average. After the RM technology trial, the benefit from the device was validated by noteworthy improvements for most participants on at least two of the measures (Table 4). Previous investigations have utilized additional test measures and questionnaires (e.g., Rance et al., 2014; Schafer et al., 2013, 2014b, 2016) that would likely be sensitive for evaluating pre-post benefit from RM technology. Overall, given the common auditory sensitivities and poor auditory processing in individuals with ASD, RM technology is an important consideration. The proposed three-step approach will ensure a well-controlled and evidence-focused fitting, verification, and validation of RM technology on individuals with ASD.

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Vocational Rehabilitation: Educational Audiologists' Knowledge, Attitudes, and Referral Practice Patterns

John J. Whicker[1], Faith Thomas[2], Kayla R. Currier Kipping[2], Kandace T. Jones[2], Brenda K. Smith[3] and Karen Muñoz[1]

[1]Department of Communicative Disorders and Deaf Education, Utah State University, Logan UT
[2]Department of Special Education and Rehabilitation, Utah State University, Logan UT
[3]Center for Persons with Disabilities, Utah State University, Logan UT

Corresponding author:
John J. Whicker
jj.whicker@aggiemail.usu.edu
2620 Old Main Hill
Logan, UT 84322
435-797-9234

ABSTRACT

This study explored educational audiologists' knowledge, attitudes, and referral practice patterns regarding vocational rehabilitation for transitioning adolescents with hearing loss. Educational audiologists across the United States were recruited to take part in an online, cross-sectional survey. Responses were analyzed for 81 respondents. Findings indicate that educational audiologists value vocational rehabilitation as important for their transitioning students; however, educational audiologists' knowledge about vocational rehabilitation may be limited, which may perpetuate student and family misconceptions about vocational rehabilitation. Suggestions for improvement are discussed.

Despite the normal distribution of intelligence and aptitudes, young adults with hearing loss may experience more difficulty transitioning from school to adulthood, receive less post-secondary education, and have a higher rate of unemployment when compared to typically hearing peers (Punch, Hyde, & Creed, 2004). In a recent national outcomes study, Garberoglio, Cawthon, and Sales (2017) reported that individuals who are deaf or hard-of-hearing (DHH) generally achieve lower levels of education compared to typically hearing cohorts, with only 18% of individuals who are DHH attaining a baccalaureate degree compared to 33% of hearing individuals. Attainment of higher education is especially lower among individuals who are DHH with other disabilities (Garberoglio et al., 2017). In 2016, only 48% of individuals who are DHH were employed, compared to 72% of hearing individuals; individuals who are DHH with other disabilities showed the lowest rate of employment (Garberoglio, Cawthon, & Bond, 2016). Employment has been linked to increased quality of life for individuals with varying disabilities (Rueda, Raboud, Mustard, et al., 2011; Beyer, Brown, Akandi, & Rapley, 2010). Thus, how transitioning young adults with hearing loss are supported as they find and maintain integrated employment has implications for their quality of life following their transition to adulthood.

Some studies have explored the career development of students with hearing loss to understand why a poor association between employment and hearing loss exists. For example, the extent to which students perceive their hearing loss as a communicative barrier and social restriction can influence how likely they are to explore ambitious career options (Punch, Creed, and Hyde, 2005; Punch & Hyde, 2005). In a sample of students using visual language as a primary mode of communication (N=53), 77% did not achieve a passing grade on the Transition Competency Battery (TCB; Bullis & Reiman, 1992), indicating that students demonstrated limited attainment of employment skills (e.g., job-seeking, social-interpersonal skills) and independent living skills (e.g., money management, community awareness; Luft & Huff, 2011).

Finally (and as alluded to by Garberoglio and associates (2017)), research suggests that the association between hearing loss and unemployment is accentuated for females, those with comorbid disabilities, those who had hearing loss at a younger age, and those who achieved lower levels of education (Moore, 2002; Hogan, O'Loughlin, Davis, & Kendig, 2009). Findings from these studies suggest that many transitioning adolescents with hearing loss may not be receiving evidence-based transition services. Transition services are evidence-based when they adhere to quality research indicators (e.g., career awareness, social skills, parent involvement; see Mazzotti, Rowe, Sinclair, et al., 2016) in efforts to aid youth in successfully exiting high school and transitioning to post-secondary education or work settings that match the students' strengths, interests, preferences, and needs (National Technical Assistance on Transition, 2017). Although speculative, there is a possibility that students may lack confidence in taking the necessary steps to achieve competitive, fulfilling employment.

Given the implications for how adolescents with hearing loss prepare for adulthood, consideration of the role of vocational rehabilitation (VR) in helping these individuals achieve integrated, competitive employment is warranted. The Individuals with Disabilities Education Act (IDEA, 2004) outlines that a student has gained integrated competitive employment when he or she (1) is compensated for their work at or above minimum wage, (2) is employed in a setting with other workers who do not have disabilities, (3) works an average of 20 hours or more per-week, and (4) has been employed for 90 days at any time in the last year. VR is a federally-funded program to assist individuals with disabilities in finding and maintaining such integrated and competitive employment through a wide variety of services. Services are provided on a case-by-case basis; however, for individuals with hearing loss, VR services may include educational and vocational assessments, employment plans, career counseling, interpretation, vocational training, rehabilitative technology services (e.g., hearing aids), job development, job placement and follow-up, and post-employment services (Mascia & Mascia, 2008).

Research exploring the effects of VR services on employment for individuals with hearing loss is minimal; however, evidence suggests that individuals with hearing loss who receive VR services, including rehabilitative technology services, are more likely to achieve integrated employment status than those who do not receive services (Boutin & Wilson, 2009). In a national outcomes study exploring the effects of VR services on gainful employment for individuals with sensory/communicative disorders, physical disorders, and mental health disorders, 62% of individuals achieved gainful employment after receiving VR services (Dutta, Gervey, Chan, Chou, & Ditchman, 2008). In the same outcomes study, individuals with sensory/communicative disorders had the highest success rate (75%), with diagnostic and treatment services and rehabilitative technology services specifically contributing to the outcomes for this group.

Given the potential benefit of VR services for individuals with hearing loss, understanding how students are informed about VR services during transition from school to adulthood should be considered. As of 2012, a national study revealed only 4.6% of students with hearing loss were receiving transition services in school, and only 8% were receiving rehabilitation counseling (Gallaudet Research Institute, 2013). Although speculative, these small numbers were likely only reflective of transition-age students with an Individualized Education Program (IEP). By law, schools must include any agency that will pay for transition services in transition IEP meetings, beginning (in many states) at 14 years of age (IDEA, 2004). Although not all transition-age students with hearing loss have an IEP, many may still be eligible to receive VR services. Thus, without the IEP, it may be that many students with hearing loss are not directed to appropriate transition services and supports.

One area worth exploring is the role of educational audiologists, who can be instrumental in providing information and resources to students with hearing loss as they transition from school to work. To our knowledge, research exploring what educational audiologists know about VR services and how often VR is addressed with students with hearing loss has not been conducted. Such research can clarify existing gaps in what educational audiologists currently do in terms of referral practices and how such practices can be improved to benefit transitioning students with hearing loss. The purpose of this study was to explore educational audiologists' knowledge of, attitudes towards, and referral practice patterns for VR services for students with hearing loss.

METHOD

Respondents

This study employed a cross-sectional survey design. Cross-sectional designs are useful when gathering data from a group of individuals at a single point in time and eliminates the risk of losing data over time (Busk, 2005). Educational audiologists practicing in the United States and providing services to transitioning adolescents were notified of the opportunity to participate through a one-time email delivered through the Educational Audiology Association (EAA) list-serve, as well as through direct links posted four separate times to Facebook groups dedicated to audiologists with information targeting educational audiologists, specifically. Due to the potential overlap of sampling through the two recruiting methods, it is unclear how many educational audiologists were invited to participate, nor do we know the response rate for this survey. This study received ethical approval from the Utah State University Institutional Review Board.

Instrument

An unpiloted, 11-item survey was developed by the researchers to obtain demographic information, as well as to measure educational audiologists' knowledge of VR, attitudes toward VR, and referral practice patterns for VR. Questions primarily used a rating scale format to address how often participating educational audiologists engage in certain practices to connect transitioning students to VR services (Cronbach's $\alpha = 0.919$), and how much participating educational audiologists agree/disagree with statements regarding the role of VR services for individuals with hearing loss (Cronbach's $\alpha = 0.311$; see limitations in the discussion section of this paper). To elicit information about what educational audiologists know about VR, what they would like to know about VR, and what challenges educational audiologists face related to VR services, three open-ended questions were asked at the end of the survey. All data were collected and maintained in Qualtrics, a secure online data collection platform.

Analysis

Descriptive data analysis was completed using SPSS v 24, including measures of central tendency to identify variance in practice patterns. Cross-analysis using a one-way analysis of variance (ANOVA) was completed using an alpha level of .05 to determine if years in practice had a significant effect on educational audiologists' referral practice patterns to VR.

All written responses were reviewed separately by three of this study's authors and coded for emerging themes and subthemes. Following the separate analysis, the three authors met to discuss differences in findings and create a 100% consensus for the qualitative data (differences between researchers were primarily lexical in nature, and the consensus was regarding how themes and subthemes were worded). Apart from themes, based on the qualitative results exploring educational audiologists' knowledge about VR, the second author, a Transition Specialist with 20 years' experience, coded each of the responses according to their level of accuracy.

RESULTS

Responses to survey questions were not forced and many questions had a different number of responses. For the demographic and rating scale questions, data were completed and analyzed for 81 educational audiologists. For the open-ended responses, data were analyzed for 66 (*What do you know about Vocational Rehabilitation?*), 47 (*What do you want to know about Vocational Rehabilitation?*), and 58 (*What challenges have you/do you face regarding Vocational Rehabilitation services?*) educational audiologists. Demographic data can be viewed in Table 1. The average age of the respondents was 43 years (SD=10), with an average of 17 years (SD=11) working as an educational audiologist. The geographic representation of educational audiologists was well spread, with most respondents (55%, n=45) representing the Midwest and Western United States. Of the 81 educational audiologists, 75% (n=61) reported they routinely refer their transitioning students to VR.

Table 1. Demographics (N=81)

	%(n)	*M*(SD)
Age		
25-35	32(26)	
36-45	27(22)	
46-55	22(18)	
56-65	14(11)	
PNA	5(4)	
		43(10)
Gender		
Male	6(5)	
Female	94(76)	
Race		
White/Caucasian	93(75)	
Hispanic/LatinX	4(3)	
Black/African-American	1(1)	
PNA/Other	2(2)	
Geographic Location		
Midwest	28(23)	
West	27(22)	
Southeast	19(15)	
Northeast	14(11)	
Southwest	11(9)	
PNA	1(1)	
Years in Practice		
1-10	42(34)	
11-20	20(16)	
21-30	25(20)	
31-40	12(10)	
PNA	1(1)	
		17(11)
Refer Students to VR		
Yes	75(61)	
No	25(20)	

PNA = Preferred not to answer; VR = Vocational Rehabilitation

Respondents indicated how often they complete certain referral practices using a rating scale ranging from 1 (Never) to 5 (Always). To observe the trend of interest (how many respondents complete certain referral practices most of the time) *often* or *always* were combined (see Table 2). A majority of respondents reported they often or always explain VR to transitioning students (67%, n=54) and their parents (55%, n=44), with a verbal explanation about VR to transitioning students (66%, n=54) and their parents (59%, n=48). Fewer reported they often or always provide written information about VR to transitioning students (40%, n=32) and their parents (36%, n=29). Only 28% (n=23) reported they often or always provided online resources regarding VR to transitioning students, and 28% (n=23) often or always followed-up with students after making a referral to VR services.

Respondents next indicated how much they agree or disagree with statements regarding the value of VR services for transitioning students with hearing loss on a rating-scale ranging from 1 (Strongly disagree) to 6 (Strongly agree). For reporting purposes, *strongly disagree, disagree,* and *somewhat disagree* were combined, as well as responses for *somewhat agree, agree,* and *strongly agree* (see Table 3). A majority of respondents agreed to some extent that informing transitioning students about VR is important (97%, n=79), connecting transitioning students with their local VR office is important (94%, n=76), VR services are beneficial to transitioning students with hearing loss (90%, n=73), transitioning students are generally receptive of VR referrals (80%, n=64), and respondents feel comfortable making VR referrals (77%, n=62). Additionally, a majority of respondents disagreed to some extent that students using a visual language as a primary mode of communication rarely need VR services to be successful (91%, n=74), and that students using listening and spoken language as a primary mode of communication rarely need VR services to be successful (88%, n=71).

A one-way ANOVA was calculated to determine if educational audiologists' years in practice had a significant effect on whether they routinely referred students to VR, and no signficaint effect was found ($F[1,79] = .049$, $p = .825$). Additionally, a one-way ANOVA was calculated to determine if educational audiologists' years in practice had a signficant effect on whether they do certain practices to connect transitioning students to VR services, and no significant effect was found ($F[26,54] = 1.592$, $p = .075$). Thus, years in practice did not influence the referral practice patterns of educational audiologists.

Table 2. Referral practices

	%(n)				
How often do you . . .	Never	Seldom	Sometimes	Often	Always
Provide verbal information to transitioning students regarding VR	4(3)	9(7)	21(17)	38(31)	28(23)
Provide written information to transitioning students regarding VR	11(9)	20(16)	28(23)	21(17)	19(15)
Take time to explain what VR is to transitioning students	4(3)	10(8)	19(15)	35(28)	32(26)
Provide online resources to transitioning students regarding VR	15(12)	27(22)	30(24)	16(13)	12(10)
Follow up with students after referring them to VR	17(14)	19(15)	33(27)	22(18)	6(5)
Provide verbal information to transitioning students' parents regarding VR	7(6)	9(7)	24(19)	37(30)	22(18)
Provide written information to transitioning students' parents regarding VR	14(11)	24(19)	26(21)	21(17)	15(12)
Take time to explain what VR is to transitioning students' parents	10(8)	11(9)	25(20)	31(25)	24(19)

Table 3. Attitudes regarding vocational rehabilitation

	%(n)					
How much do you agree/disagree with the following statements?	Strongly disagree	Disagree	Somewhat disagree	Somewhat agree	Agree	Strongly agree
VR services are beneficial to my transitioning students	4(3)	1(1)	5(4)	20(16)	44(36)	26(21)
Students who use spoken language rarely need VR services to be successful	20(16)	42(34)	26(21)	9(7)	4(3)	0(0)
Students who use visual language rarely need VR services to be successful	38(31)	48(39)	5(4)	5(4)	3(2)	1(1)
It is important to let my transitioning students know about VR service options	1(1)	0(0)	1(1)	7(6)	42(34)	48(39)
It is important to me to be connected with someone from my local VR offices	1(1)	3(2)	3(2)	17(14)	42(34)	35(28)
I am comfortable making referrals to VR	5(4)	9(7)	10(8)	15(12)	32(26)	30(24)
Generally, my students are receptive of VR referrals	1(1)	5(4)	14(11)	36(29)	35(28)	9(7)

Three open-response questions were used to elicit written responses regarding what educational audiologists know about VR, what they want to know about VR, and challenges they face when working with VR. The following is a qualitative description regarding each question.

What do you know about Vocational Rehabilitation?

Sixty-six educational audiologists (81%) responded to this question. One major theme emerged regarding the *knowledge type* pariticipants were reporting. Four subthemes emerged and indicated that, of those who responded, 85% (n=56) reported knowledge about general VR services, 38% (n=25) reported knowledge about eligibility criteria to receive VR services, 17% (n=11) reported specific knowledge regarding postsecondary educational services provided for by VR, and 6% (n=4) reported knowledge regarding transition procedure and wait-times. Some educational audiologists provided responses that illustrated knowledge in multiple knowledge type subthemes. These respondents were tallied in each knowledge type with which their response corresponded.

Responses were also coded to reflect the level of accuracy for each response, called knowledge level. Educational audiologists were categorized as having inaccurate knowledge (58%, n=38) (e.g., provided an inaccurate list of services, thought that services were only available after a transitioning student graduated or exited secondary school), limited knowledge (35%, n=23) (e.g., demonstrated knowledge about an aspect of VR but not all), or no knowledge (8%, n=5). No educational audiologists provided a full, accurate description of the scope and services of VR (see Table 4).

What do you want to know about Vocational Rehabilitation?

Forty-seven educational audiologists (58%) responded to this question, and two themes emerged related to the *structural* aspects of VR and the *procedural* aspects of VR. For *Structural,* three subthemes emerged indicating that respondents wanted more information regarding services, resources, and assessments (36%, n=17), eligibility and funding (17%, n=8), and staffing and training (6%, n=3). For *Procedural*, two subthemes emerged indicating that respondents wanted more information regarding the referral process or connecting with VR offices (34%, n=16), or general information about the process of obtaining VR services (15%, n=7). Nineteen percent (n=9) of the respondents reported they did not want to know anything more. Some respondents provided responses that illustrated desired knowledge in multiple themes. These respondents were tallied in each knowledge type with which their response corresponded (see Table 5).

Table 4. What Educational Audiologists Know About Vocational Rehabilitation (N=66; 81%)

Knowledge Type	%(n)	*Example*
General Services	85(56)	"VR helps students with educational/vocational needs as well as help with some transportation/living costs if approved."
Eligibility	38(25)	"In our state, voc rehab provides specialized employment and education-related services and training to assist teens and adults with disabilities in becoming employed or retaining employment."
Educational Services	17(11)	"Provides assistance to students seeking higher education and written rehab plans or devices to help students succeed in their education."
Transition Procedure	6(4)	"It is hard to get services in a timely manner; usually a waiting list for the students."
Knowledge Level		
Inaccurate	58(38)	E.g., inaccurate list of services; thought that services were only available to already-transitioned adults
Limited	35(23)	E.g., demonstrated knowledge about some but not all aspects of VR
None	8(5)	"Not very much-I am not really sure what is even available in my county."

Table 5. What Educational Audiologists Want to Know About Vocational Rehabilitation (N=47; 58%)

Theme	%(n)	*Example*
Structural		
Services/resources/assessments	36(17)	"Exactly the process to be evaluated, who qualifies, how they can be invited to the IEP."
Eligibility/funding	17(8)	"My families are not interested in Voc Rehab because they feel like it's for "poor people" and only for "real deaf people". I'd like to become more familiar with their service criteria so I don't perpetuate misinformation."
Staffing/training	6(3)	"What is training of those that work with deaf and hard of hearing clients?"
Procedural		
Referral process/VR connection	34(16)	"I would like to know a contact at my local office."
General information	15(7)	"Better knowledge of how the process works and how I can further expedite the process for kids."
No knowledge needed	19(9)	"I don't really need anything, I pretty much know what voc rehab does in my county."

What challenges have you/do you experience regarding Vocational Rehabilitation services?

Fifty-eight educational audiologists (72%) responded to this question, and the same two themes emerged related to the *structural* aspects of VR and the *procedural* aspects of VR. For *Structural*, three subthemes emerged indicating that respondents were facing challenges related to eligibility and funding for their students (26%, n=15), staffing and training concerns (22%, n=13), and services, resources, and assessments used (9%, n=5). For *Procedural*, three subthemes emerged indicating challenges related to making referrals and connecting with VR offices (24%, n=14), adequate follow-through or follow-up from VR once making a referral (24%, n=14), and having access to general procedural information (5%, n=3). Nine percent (n=5) of the respondents indicated they faced no challenges regarding VR. Some respondents provided responses that illustrated challenges in multiple themes. These respondents were tallied in each knowledge type within which their response corresponded (see Table 6).

Discussion

The purpose of this study was to explore the knowledge, attitudes, and referral practice patterns of educational audiologists who work with transitioning adolescents with hearing loss. This study is the first to explore this topic. The results of this study can be used to improve the knowledge and referral practice patterns of educational audiologists, with the ultimate goal of ensuring that adolescents with hearing loss are adequately informed and connected with transition services provided by VR.

Overall, educational audiologists' attitudes regarding VR are positive, with a vast majority valuing VR services as important for their transitioning students. Despite this high value, referral practices are variable and likely imprecise. For example, while most audiologists provided verbal information to both students and parents regarding VR services, based on the qualitative data, the information provided appears to be incorrect or incomplete, as no respondents were able to provide a full, accurate description of the scope and services of VR. The authors note, however, that limitations exist in the current interpretation of this qualitative data, which are discussed further on.

Table 6. Educational Audiologists' Challenges Regarding Vocational Rehabilitation (N=58; 72%)

Theme	%(n)	*Example*
Structural		
Eligibility/funding	26(15)	"Sometimes our county VR doesn't have a lot of money to help students . . ."
Staffing/training	22(13)	"The office closest to my students is not as familiar as I would like with hearing services. I often have to refer my students to an office in a larger town (30 miles away) in order to obtain hearing services."
Services/resources/assessments	9(5)	"Need more info on their services."
Procedural		
Referrals/VR connection	24(14)	"In my position I also work with a large geographical area so there are different offices or individualized handling things so not always sure who to contact."
Follow-through/follow-up	24(14)	"Patients have reported difficulty obtaining services through state rehab services or that it took a really long time to get any support."
General information	5(3)	"Having up to date information."
No challenges	9(5)	"None really, I have a good relationship with the voc rehab people."

Some incongruencies between the quantitative and qualitative data exist. For example, 77% of respondents agreed to some extent that they feel comfortable making VR referrals, however many wanted more information or faced challenges regarding having connections with VR offices. Thus, it is unclear exactly what "making referrals" means from the results of this study, given that many may consider simply talking about VR as making a referral, without providing contact or other information to help students connect with their specific local VR counselor who services individuals with hearing loss. This is a limitation that can be addressed in future studies.

Among individuals with hearing loss and their families, misconceptions may exist about VR and its scope of services. Fewer individuals who are hard-of-hearing take advantage of VR services compared to individuals with profound hearing loss or deafness (Moore, 2001). Some of the qualitative data from this study reflect why this may be. For example, one educational audiologist reported, "My families are not interested in Voc Rehab because they feel like it's for poor people and only for real deaf people".

Other misconceptions may exist among the educational audiologists. From the qualitative data, it is unclear how many understand that VR services are intended for individuals with disabilities, rather than the general population. Furthermore, several audiologists indicated in their open responses that they did not know that individuals can access VR services as early as 14 years of age, nor was there any indication that educational audiologists were supporting students to access pre-employment transition services provided by VR in their secondary settings.

Implications for Practice and Research

Given that educational audiologists report routinely referring students to VR, the number of educational audiologists who may be providing inaccurate or incomplete information may indicate that misconceptions regarding VR are being perpetuated, such that eligible students with hearing loss are not seeking the services from which they may benefit. Some suggestions to mitigate this are: (1) educational audiologists contact their local VR counselors via contact information provided on the agency website or through the local high schools; (2) once educational audiologists have made contact with their local VR counselors, they may also request pamphlets or other written material to share with students and their families regarding VR services, and seek to increase in collaborative work with VR counselors; (3) when contacting the local VR office, the educational audiologist can request the name of the VR counselor who specifically supports individuals with hearing loss, and (4) if the student has an Individualized Education Program (IEP), the educational audiologist can obtain written permission from the parents (or emancipated student) for a VR counselor to attend IEP meetings, explain their services, and be a part of the transition IEP team as they begin transition planning once the student turns 16 years of age (or, in many states, at the age of 14).

This study is not without limitations. The procedure for collecting data (online, cross-sectional survey) did not allow for follow-up questions when qualitative responses were unclear. It is possible that the 58% of respondents who provided inaccurate statements about VR could have provided more accurate statements with follow-up questioning regarding their responses. Additionally, this study did not explore how educational audiologists determine which students need VR referrals, as it may be that educational audiologists only make referrals on a case-by-case basis, which was not explored in this study. Finally, the instrument used in this study was not totally reliable, as the scale to measure what educational audiologists agree/disagree with regarding the role of VR for students with hearing loss had minimal internal consistency. Future studies could enhance the findings of this study by exploring specifically how and why educational audiologists make referrals to VR and what specific information they provide. Finally, future studies could explore how effective online resources and written information are in increasing student and family knowledge about VR, which is something this study did not explore.

CONCLUSIONS

The purpose of this study was to explore the knowledge, attitudes, and referral practice patterns of educational audiologists regarding VR. Findings from this study reveal that educational audiologists value VR services as important for their students; however, many educational audiologists may not be providing accurate information about VR and may perpetuate misconceptions which students and their families may have about VR services. Further research to understand educational audiologists' relationship with VR is recommended to improve post-secondary and employment outcomes for students with hearing loss.

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