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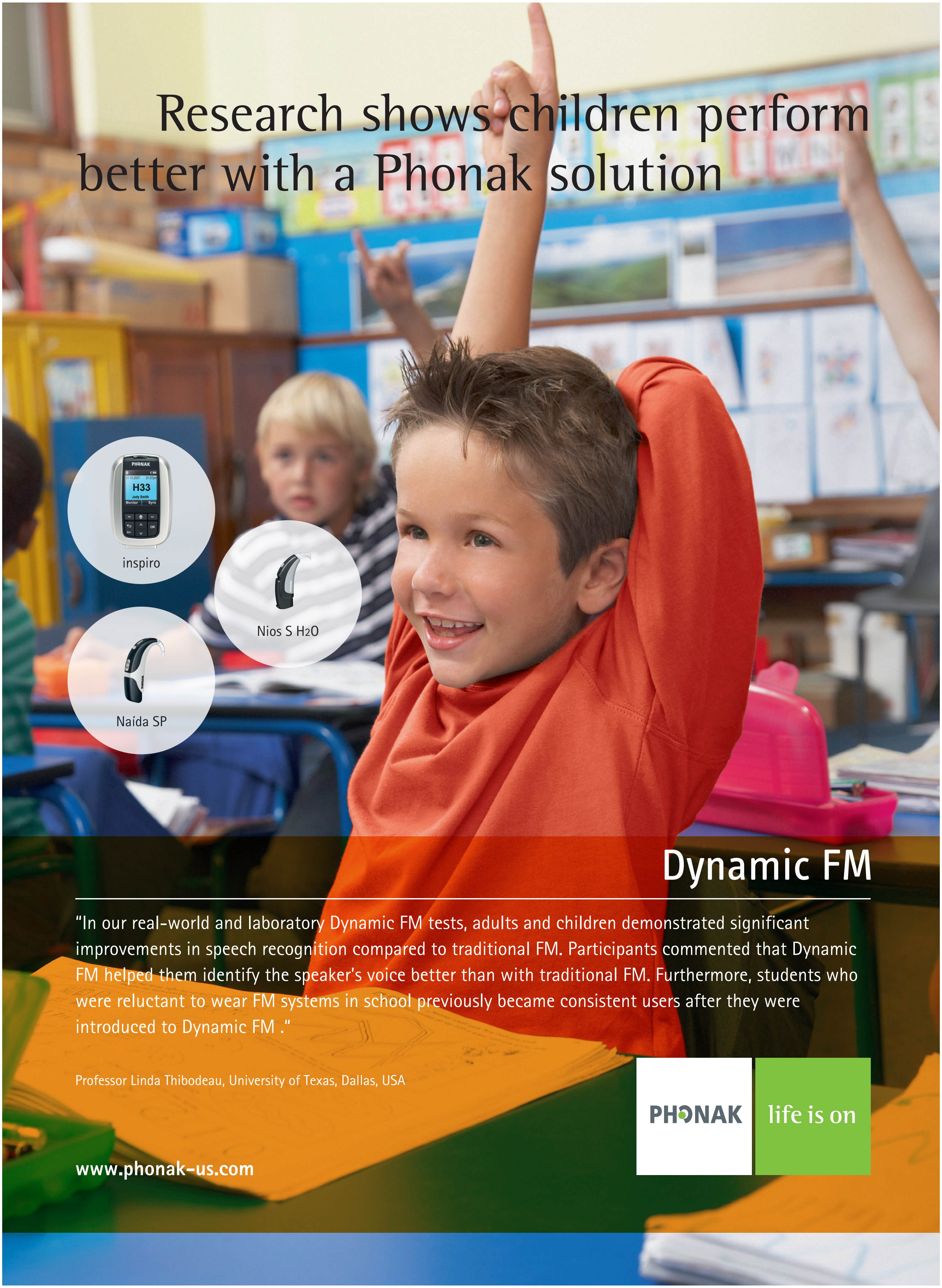
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Counseling Strategies for Tweens and Teens with Hearing Impairment

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Akron, OH

Adolescence can be a turbulent time, and teens need all the help they can get. When they have a hearing loss, do they consider their audiologists part of their support system? We can expand our care from "tech support" to "moral support" and beyond, by taking time to understand their psychosocial development and also giving them time to talk to us. The following article will describe adolescent cognitive development and related "thinking errors," the challenges in developing a self-identity, and two counseling strategies designed to give tweens and teens practice in self-expression and self-understanding.

Introduction

Child psychologist Haim Ginott (1969) described adolescence as a "period of curative madness, in which every teenager has to remake his personality. He has to free himself from childhood ties with parents, establish new identification with peers, and find his own identity" (p. 25). This "curative madness" requires tweens (ages 11-12) and teens (ages 13-19) to deal with peer groups and physiologic changes, while asking themselves, who am I and what do I want from my life? Self-consciousness increases as well as uncertainty and mood swings. Add hearing impairment to this adjustment process, and we are likely to encounter teens struggling to cope.

Audiologists can support this adjustment process by expanding their role to provide, not only technical support, but also "sounding board" or counseling support.Teens and tweens benefit from conversations with adults, especially when the conversation means "teens talk more, adults talk less." This article will describe two issues to keep in mind as we consider our role as counselor to teens and tweens: adolescent brain development and the development of self-identity. A set of simple counseling strategies will also be offered.

Adolescent Brain Development

Much has been written in the last decade about brain development during the teen years. Parents, teachers, advisors, and others now have the science to confirm what they have long observed: that teens are not young adults in the neurocognitive sense. Although their bodies have reached adult proportions, teens' brains are still developing, most importantly in the area of the frontal cortex. This "executive center" of the brain is involved with judgment, organization, planning, and strategizing. As teens begin to mature, their frontal lobes begin to thicken with gray matter (Philp, 2007). During this developmental stage, teens may be sufficiently mature to design and carry out a complex action, but not realize until perhaps years later that the action may have been inappropriate or immature (Sylwester, 2007).

Merrell (2007) describes some common thinking errors observed in teens as their frontal cortex is developing:

- <u>Binocular vision</u>: looking at things in a way that makes them seem bigger or smaller than they really are. Example: Tina came in last in a 100-meter race. She now thinks she is the worst athlete who ever joined this team.
- <u>Black-and-white thinking</u>: looking at a situation only in extreme or opposite ways (only good or bad, never or always, all or none). Example: Sam disliked leaving lunch to attend speech therapy twice a week. He thinks it will never make a difference anyway.
- <u>Dark glasses</u>: thinking only about the negative parts of things. Example: Anabelle's chemistry teacher praised her improved work in class and suggested that, if she had studied the chapter discussion questions, she might have done even better on the last test. Annabelle was upset about how poorly she had studied for the test.
- <u>Fortune-telling</u>: Making predictions about what will happen in the future without enough evidence. Example: Josef asked a girl from algebra class to a dance, but she said she already had a date. He decided not to ask anyone else because he knew no one would ever want to go out with him.
- <u>Blame game</u>: blaming others for things you should take responsibility for. Example: Mary did not have spare batteries and took a spelling test with dead hearing aids. She did poorly on the test but felt it wasn't her fault because she couldn't hear the teacher.

(Readers may recognize some of these thinking errors occurring in adults as well.)

Our first inclination may be to correct these thinking errors when they occur; however, a correction approach is more likely to result in defensiveness rather than clarification. A teen's cognitive development is not "stuck" in these thinking errors forever, but at the moment, he or she is probably not ready to advance to more productive or positive thinking, especially if currently upset or distraught. It is a challenge, but adults are advised to refrain from pointing out the thinking errors directly. In a subsequent section, we will explore several indirect approaches that encourage teens to think about alternatives and options.

Development of Self-Identity

In addition to managing changes in thinking and problem-solving, teens have additional work to do. Other developmental tasks of adolescence are described by Stepp (2000), who organized these tasks into a set of questions: (1) What kind of a person am I?; (2) How do I fit in with friends?; (3) What am I learning in and out of school?; (4) How can I create distance yet remain connected to adults?

What kind of person am I? Am I competent? What am I good at? Am I normal? Teens are scrutinizing their self-concept and deciding to accept or reject it. They are beginning to establish their adult identity, and when they have a hearing loss, they must incorporate that disability into this new identity, often without role models. Because most teens with hearing impairment attend their neighborhood schools, and are likely to be the only student with hearing loss in their school (National Association of State Directors of Special Education, 2011), they might be struggling to define an identity in a vacuum.

It may surprise audiologists to know that teens might even be asking themselves, "Am I hearing or hearing impaired?" The challenge to clarify "who I am" can get complicated when amplification devices are especially successful. For instance, a 14-year boy shared this observation: "[because of my cochlear implant] everyone thinks I am hearing. To be honest inside me I'd say I'm hearing because I can hear what everyone is saying" (Wheeler et al., 2007, p. 311). The researchers who conducted this interview pointed out that to perceive oneself as hearing could create confusion for the deaf or hard of hearing teen.

How do I fit in with friends? Peers provide a unique validation that parents cannot provide (Blakemore, 2008). The pressure to be like one's peers is great, and the use of amplification can seem an intolerable difference.

As teens seek out peers, they also face the risk of rejection. "All day, teens are faced with pressure to create a space for themselves without embarrassment and to form friendships for protection and support" (Philp, 2007, p. 84). The social realm may be even more challenging when there are few or no peers to share one's experiences as a person with a hearing loss.

The fear of rejection and other age-related stressors contribute to the precipitous drop in self-esteem that occurs in adolescence. Figure 1 depicts changes in self-esteem across the lifespan, age 9 to 90. Females experience more change than males, but both genders find themselves on shaky ground during the teen years (Robins & Trzesniewski, 2005).

What am I learning, in and out of school? Teens wrestle with ethical concepts and codes of conduct as well as learning academics. They question their parents' authority, values, and expectations, and look for resolutions to these conflicts. This can be a particularly daunting task when language levels are still developing, making it difficult to discuss these kinds of abstract issues.

How can I create distance yet remain connected to adults? Stepp (2000) described an effective support system for teens as a three-legged stool, involving friends, parents, and other adults. The role of "other adults" (and hopefully audiologists see themselves in this role) is to instill sufficient confidence in the child that he or she can gradually disconnect from parents and develop autonomy with increasing self-direction and self-awareness.

Questions abound for the audiologist: Do we see ourselves as a support system for teens during this time of transition? Can we help in the transfer of ownership of hearing loss from parent to teen? Can we provide opportunities for teens to determine their own goals, define their best self-interests, and become confident and knowledgeable self-advocates? Can we facilitate self-

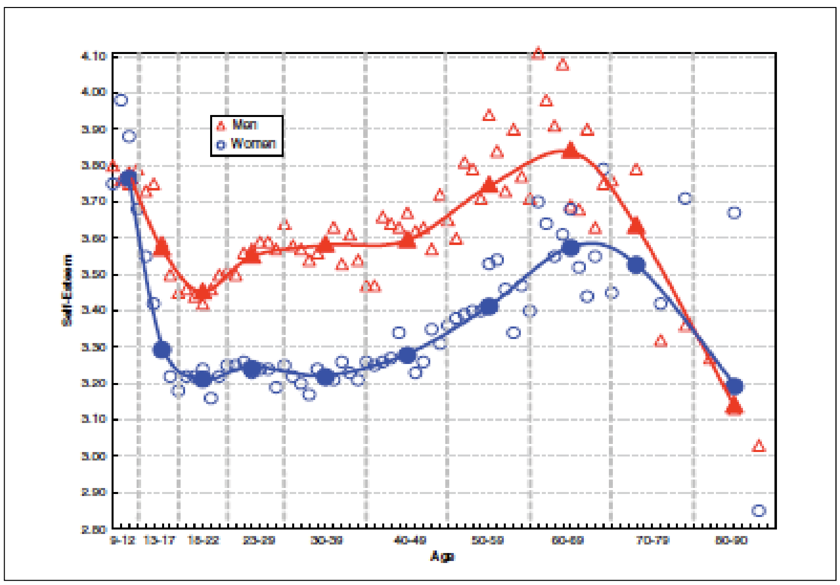

Figure 1. When children enter their teen years, their sense of self-esteem is deeply affected, females more than males, according to the Single-Item Self-Esteem Scale: "I see myself as someone who has high self-esteem." (N = 326,641). From "Global Self-Esteem Across the Lifespan," by R. W. Robins, K.H. Trzesniewski, J.L. Tracy, S.D. Gosling, and J. Potter, 2002, *Psychology and Aging, 17*, p. 428. Copyright 2002 by the American Psychological Association. Reprinted with permission.

expression, self-awareness, and self-acceptance as an individual with hearing loss?

The answer to these questions can be *yes*, especially if we actively "mind the gap" (Figure 2). Signs in the London subway system warn passengers to "mind the gap" between the platform and train. There is also a figurative gap between audiologist and teen, but not an insurmountable one. Audiologists can bridge the gap by taking a step into the teen's world, rather than expect teens to be interested in our world.

Teens learn to expand their cognitive development, described earlier, by practicing problem-solving, decision-making, and self-expression. Sylwester (2007) maintains that the best way to help teens understand their own development is through conversation. Granted, adolescent frontal lobes may not be mature, but they are developing; we can enhance that development by "elevating the rational level characteristic of adult conversation, even if it doesn't always work" (p. 92). Audiologists can provide this needed practice with some simple counseling strategies, described in the next section.

Counseling Strategies

Before we can hope to address adolescents' audiologic rehabilitation needs, we may need to establish a different relationship with them than the one we might have had when they were children. This **transitional relationship** will not happen automatically. The audiologist needs to consider how to facilitate conversations that are meaningful to the teen, without artifice. But how?

Table 1 lists two simple strategies: (1) open up a conversation and (2) keep the conversation going. Examples of how to do so follow. Note that we may need to make a concerted effort to talk about topics other than school and hearing!

Figure 2. A sign found throughout the London subway system cautions patrons to attend to the space between platform and train. It can also serve as a reminder about the "space" between audiologists and teens. Photo credit: K. English.

Open Up a Conversation: How?

This first strategy likely sounds too obvious, but its purpose is to remind us that what we think is interesting is probably not what teens think is interesting. If we realize that the only thing we talk about with teens is amplification, for instance, then we do need to stretch our repertoire.

Talk about something they want to talk about. Who are these individuals, and what makes them interesting? Almost any topic will do: video games, sports, hobbies, extra-curricular activities, and movies could be topics teens might want to talk about. Ask them, "What do you do in your free time these days?" and go from there. Teens have been known to resist conversation with adults, of course, but it is worth our effort to keep trying.

A topic almost guaranteed to engage teens is music. Ask a teen, "What is your favorite band (or singer, songwriter) right now?, Do you like all kinds of music styles or one kind more than others?", and so on. The answers are invariably enthusiastic, and no wonder: music is an especially important aspect of adolescence. Levetin (2006) reminds us of what we already know: that in our teen years, we choose the music we will love forever. Teen years are emotionally intense, so the memories we associate with music from those years are especially strong. Music from one's teen years supports the identification with peers, subgroups, and humankind, and has the extra appeal of being fun. Hearing loss affects the experience of music but usually does not preclude the enjoyment and bonding effects of music.

Talk about something they know more about than we do. The first topic in this section that comes to mind is technology. It may seem impossible to keep up with new apps, smart phones, and Internet developments, but teens usually know the latest. They are generally happy to demonstrate their knowledge.

Another topic that teens know more about than most audiologists is growing up with hearing loss. There is, of course, far more to it than just not hearing well, including the decision of when to disclose their hearing loss to others. Like all decisions, this one has its pros and cons, but it may not be often discussed.

Table 1. Two Counseling Strategies

1. Open up a conversation – not always about school and hearing!
    a. Something they like to talk about
    b. Something they know more about than we do
    c. Something that draws out their concerns and opinions
2. Keep the conversation going
    a. Minimize advice
    b. Monitor the effects of our responses

What would we learn if we provided teens a blank 4-square box like the one in Figure 3, and asked them to fill it in? Because many teens consider nonuse of amplification as a way of "fitting in," this table can be used as a framework for a conversation about this decision.

As teens and tweens consider the costs and benefits of mentioning and *not* mentioning that they have a hearing loss, or hiding/not wearing amplification, the audiologist would simply organize and summarize input. While the table (Figure 3) is being filled in, no judgment is necessary as to the wisdom or folly of these opinions. An open acceptance of any of the stated pros and cons helps bring more issues to the surface.

Talk about something that draws out their concerns and opinions. Another way of saying this is "talking about something that is personally meaningful," and that can be a challenge. However, one way to facilitate this kind of conversation is to use a questionnaire as a springboard for discussion – an indirect way to approach topics that are usually not part of everyday conversation. A questionnaire specifically designed for our target population is called the Self-Assessment of Communication – Adolescents (SAC-A) (Elkayam & English, 2003). The SAC-A (see Appendix) has been determined to be a reliable tool (Wright, English, & Elkayam, 2010) and helps audiologists to find a starting point for conversations with teens. The three sections of the SAC-A ask about a variety of listening situations as well as reactions to those situations – both the teen's and other people's. How will a teen answer Question #8: "Does anything about your hearing loss upset you?" The outcomes of the conversation are impossible to predict, but it can be hoped that at least they will have "planted a seed" about how to deal with challenges and certainly provide practice in self-expression.

The primary focus of these conversations has been on the here-and-now. At the same time, however, teens are also thinking about the future, whether it involves college, vocational training, employment, or a combination of these options. Transition planning is required for all students with Individualized Education Programs, but many teens in general education settings may lack a support system to facilitate their transitions from high school. Ideally, this kind of planning should begin in middle school to allow sufficient time to explore all options. Finding out information about details, such as accommodations, student loans, college or work site expectations, and schedules, require using new skills that are best learned with coaching, rehearsal, feedback and reflection (English, 2012).

Audiologists can broach this topic with talking points that are readily available online (specifically, the *Guide to Planning*, n.d.). Our questions about post-secondary plans could include: "What kind of support do you have at this time?" and "What kind of help do you need from me?" If teens are not open to discussing more personal aspects of their lives, they might still appreciate a conversation with their audiologist about how to manage the logistics related to their future plans.

Keep the Conversation Going: How?

This second strategy is not as easy as the first one. Once the conversation opens up, our responses can either keep it going, or shut it down. Keeping the conversation going is preferable, because, when teens and tweens have an opportunity to talk through their concerns, they become better equipped to manage those concerns. Below are two tips on keeping the conversation going.

Minimize advice. It takes practice, but we can get through a conversation with a tween or teen without dispensing advice. If a teen does ask for advice, of course we feel compelled to give it. However, listen carefully and take note over time: how often does this actually happen? What we perceive as a request for advice from a teen might in fact be a request to vent, to grieve, to share, to be listened to. If it's not clear, we can check by asking, "It sounds like you are asking for advice, but I want to be sure. Yes or no?" Even if the answer is *yes*, it could help the teen understand his or her thinking by first asking a few exploratory questions: what have you considered so far? What seems the right thing to do at this point? What would happen if you chose X and not Y? We can be sure that if advice is given when it was not requested, the conversation will lose its momentum.

Monitor the effects of our responses. It is important to monitor ourselves during these conversations, because, at any point, we could end them prematurely without realizing it. During a conversation, the manner in which we take our turn in the encounter is often overlooked (Clark

Costs of Not Disclosing It's stressful not being "upfront." Others might wonder if you are rude or aloof if you do not understand. You miss a lot of what others say to you. School work is more difficult.	**Benefits of Not Disclosing** Can feel like other kids. Teachers will treat you the same, and expect you to be as smart as other kids. Cashiers talk to you like anyone else.
Costs of Disclosing People might have a problem with it. You may not be hired a summer job, even though that's illegal. Friends assume you can't drive safely, and they won't get in the car if you are driving.	**Benefits of Disclosing** You are out in the open so no stress trying to keep up the lie of normal hearing. Others understand why you may miss something. You don't misunderstand as often. People may speak more clearly. School work will be easier because you will be able to wear your hearing aids.

Figure 3. Some possible costs and benefits of disclosing one's hearing loss.

& English, 2014). Like moves in a chess game, how we respond will directly influence the teen's next comment. Our responses can be easily categorized as *terminators* or *continuers*. *Terminators* end a conversation by only addressing the surface nature of a question or comment (Pollack et al., 2007). For example:

Teen: Do I **have** to wear these hearing aids all day?
Audiologist: Yes, you do, otherwise you will fail all your classes.

The audiologist responded with a *terminator*, with the likely outcome of the teen stomping off in anger and resenting being "treated like a baby," while being denied an opportunity for self-expression. When we only answer the surface question, we bring the discussion to a close without knowing why the question or comment was made.

Continuer responses, on the other hand, refrain from immediate solutions, and instead, intentionally elicit more input by lobbing the "conversational ball" back to the teen more often. A continuer response attempts to offer teens both empathy and the opportunity to continue expressing their thoughts and feelings. For example:

Teen: Do I **have** to wear these hearing aids all day?
Audiologist: That's a problem?
Teen: A huge problem! I feel totally wiped out by 3 o'clock. I could use a break in the middle of the day or something.
Audiologist: I can see how a break could help.
Teen: I was thinking about taking them off during lunch – I pretty much know what my friends are going to say, anyway. I could kinda space out and not concentrate so much.
Audiologist: That sounds logical. If you try it out, let me know how it goes. We haven't discussed "listening effort" and "listening fatigue" before, but I'll find some info if you're interested.

These two dialogues started out the same, but ended up quite differently because of the audiologist's response. One responsewas an immediate answer to the surface question; the other set of responses stayed neutral, were slow to solve problems but took the time to find out what inspired the question, and waited to see if the teen had any ideas of her own.

As stated earlier, we cannot predict the outcomes of these conversations with teens. However, they is worth the effort. Occasionally, we see an immediate positive outcome, and if not, we can at least hope a seed of trust was planted.

Conclusion

Our counseling conversations with teens can help them practice self-expression, fine-tune their problem-solving skills, and modulate their initial emotional responses to stressful situations. Audiologists are in a unique position to "grow" adolescent brains and support teens' overall development by offering opportunities for adult conversations about decisions, choices, consequences, and identity. We just need to watch out for those "terminators."

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SELF ASSESSMENT OF COMMUNICATION-ADOLESCENT (SAC-A)*

Judy Elkayam, Au.D. and Kris English, Ph.D.

The purpose of this questionnaire is to identify problems you may be having because of your hearing loss. We will talk about your answers. That conversation may help us understand the effect the hearing loss is having on you. It may also give us ideas to help you manage those problems. The information you give will not affect your grades in school.

Please circle the most appropriate answer for each of the following questions. Select only one answer for each question. If you usually use hearing aids or cochlear implants, answer each question in a way that describes your experiences with the technology on. If you do **not** usually use hearing aids or cochlear implants, answer each question in a way that describes your experiences without the technology.

Student Name ____ Date ______________________________

Technology Use

I usually do/do not use hearing aid(s) I usually do/do not use cochlear implant(s)

Hearing and Understanding at Different Times

1. Is it hard for you to hear or understand when talking with only one other person?	**1 = almost never**	**2 = occasionally**	**3 = about half the time**	**4 = frequently**	**5 = almost always**
2. Is it hard for you to hear or understand when talking with a group of people?	**1 = almost never**	**2 = occasionally**	**3 = about half the time**	**4 = frequently**	**5 = almost always**
3. Is it hard for you to hear or understand TV, the radio or CDs?	**1 = almost never**	**2 = occasionally**	**3 = about half the time**	**4 = frequently**	**5 = almost always**
4. Is it hard for you to hear or understand if there is noise or music in the background, or other people are talking at the same time?	**1 = almost never**	**2 = occasionally**	**3 = about half the time**	**4 = frequently**	**5 = almost always**
5. Is it hard for you to hear or understand in your classes?	**1 = almost never**	**2 = occasionally**	**3 = about half the time**	**4 = frequently**	**5 = almost always**
6. Do you hear better when using your hearing aids or cochlear implants?	**1 = almost never**	**2 = occasionally**	**3 = about half the time**	**4 = frequently**	**5 = almost always**

Feelings about Communication

7. Do you feel left out of conversations because it's hard to hear?	**1 = almost never**	**2 = occasionally**	**3 = about half the time**	**4 = frequently**	**5 = almost always**
8. Does anything about your hearing loss upset you?	**1 = almost never**	**2 = occasionally**	**3 = about half the time**	**4 = frequently**	**5 = almost always**
9. Do you feel different from other kids when you are wearing your hearing aids or cochlear implants?	**1 = almost never**	**2 = occasionally**	**3 = about half the time**	**4 = frequently**	**5 = almost always**

Other People

10. Do strangers or people you don't know well notice that you have a hearing loss?	**1 = almost never**	**2 = occasionally**	**3 = about half the time**	**4 = frequently**	**5 = almost always**
11. Do other people become frustrated when they talk to you because of your hearing loss?	**1 = almost never**	**2 = occasionally**	**3 = about half the time**	**4 = frequently**	**5 = almost always**
12. Do people treat you differently when you wear your hearing aids or cochlear implants?	**1 = almost never**	**2 = occasionally**	**3 = about half the time**	**4 = frequently**	**5 = almost always**

*Modified, with permission, from Self Assessment of Communication (Schow & Nerbonne, 1982). 03/11

Technology in Educational Settings
It May Already Be In Your Pocket or Purse!

Dan Ostergren, AuD
Audiology Resources, LLC

Joseph Smaldino, PhD
Illinois State University

"Technology in Educational Settings" is the theme for the Educational Audiology Association's Summer Conference in Scottsdale, Arizona in June, 2013. The program will be filled with valuable information, particularly because of the large increase in web-based tools that have been designed to address the needs of students, teachers, and educational audiologists. Yet, audiologists might be surprised to know that one of the most useful technology tools may already be in our possession: the smartphone or tablet computer, both of which have become ubiquitous in their penetration of the consumer technology market. Today, there are powerful applications (apps) for smartphones and tablets that address almost any task or query for information. This article will review the current ANSI Standard for classroom acoustics as well as focus on apps for smartphones and tablets designed for the measurement of classroom acoustics.

Introduction

In recognition of the fact that undesirable acoustics can be a barrier to listening and learning in the classroom, the first American standard was published in 2002 and revised in 2010. The first part of the revised standard, American National Standard Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools, Part 1: Permanent Schools (ANSI/ASA S12.60-20), is a refined version of the 2002 standard. The major performance requirement for furnished but unoccupied classrooms is basically unchanged from the 2002 standard. The one-hour average, A-weighted background noise level cannot exceed 35 dB (55 dB if C-weighting is used), and for averaged sized classrooms with a volume less than or equal to 10,000 cubic feet, the reverberation time (RT60) cannot exceed 0.6 seconds (35/55 dBA/C and 0.7 seconds if the volume is greater than 10,000 but less than or equal to 20,000 cubic feet). Among other changes are improvement of the requirements for exterior walls and roofs in noisy areas, consideration of activities close to classrooms, clarification of the definition of a "core learning space," addition of the limit of 45 dBA for sound in hallways, clarification and simplification of measurement procedures and addition of the requirement that if an audio distribution systems is deemed appropriate it should provide even coverage and be adjustable so as not to disturb adjacent classes.

The second part of the revised standard, American National Standard Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools, Part 2: Relocatable Classroom Factors (ANSI/ASA S12.60-2010), includes performance requirements for portable classrooms. The current standard sets a 41 dB(A) limit for background noise in unoccupied classrooms, which would be lowered to 38 dB(A) in 2013 and 35 dB(A) in 2017. Reverberation time (RT60) in unoccupied relocatable classrooms must not exceed 0.5 second in classrooms with volumes of 10,000 cubic feet or less and 0.6 second in classrooms with volumes of 10,000–20,000 cubic feet. Both parts of the standard are available without charge from the Acoustical Society of America store (http://asastore.aip.org).

In order to estimate compliance of classroom with the ANSI (2010) standard, it is necessary to accurately and reliably measure the unoccupied noise levels and octave band reverberation times that are present in a given classroom enclosure. Obtaining accurate data regarding these parameters allows us to document compliance (or lack thereof) with the ANSI standard and affords powerful tools with which to share this information with parents, teachers, and others. These measures are not intended to replace complete acoustical analysis by certified acousticians. Instead, they are simply tools for audiologists to gather and share essential information related to the acoustical challenges students face daily in their learning environments.

There are many acoustical measurement applications (apps) that are downloadable for both Apple iOS and Android smartphone platforms. Many of these are basic sound level meters. Of these, few appear to have been designed by audio professionals for use by audiologists, or could possibly be considered equivalent to standalone, Type II sound level meters (SLMs). Others are lacking options, such as A-weighting, spectral analysis, or measures of reverberation time. While the available apps may be somewhat limited, the well-designed apps are useful and may be combined with sophisticated features that exceed our area of interest. Note that all apps are simply manipulating and displaying data that has been input to the device either via wifi, internal storage, or internal microphone. The headset input, or in the case of Apple iOS devices, the 30-pin/Lightening docking input or docking charger input may be used for input as well. Real time, direct input is our area of interest, and a review of the advantages and limitations of the various direct input methods is necessary before examining specific measurement techniques as the input method impacts the accuracy of our measurements. The following discussion is limited to Apple iOS devices (iPhone 4/4S/5, iPod Touch, and all iPad versions) as this technology, collectively, has the deepest market penetration. It is safe to assume, however, that other platforms, such as Android, have similar characteristics.

As expected, the microphone of a mobile phone, will not compare to that of an instrument-grade sound level meter. With that said, the frequency response of the iPhone/iPad's built-in microphone is fairly consistent from unit to unit. However, it has a steep, low frequency roll-off beginning at about 250 Hz of nearly 24dB/octave. App designers compensate for, or are able to override this feature to improve accuracy at low frequencies.

Another option is to use an optional microphone that connects to iPhones or iPads via the 30-pin/Lightening docking connector. However, the docking connector on older devices, such as the iPhone3GS, iPod Touch 3, and other models has an analog input. This means that the conversion from an analog signal to digital data suitable for analysis, manipulation, and display was done inside the Apple iOS device. The quality of this conversion may impact the quality of the acoustic measurements, and while analog-to-digital converter technology has reached a fairly mature state, phone manufacturers must manage costs appropriately, choosing converters that were likely not designed specifically for acoustical measurement purposes. Newer devices, such as the iPhone 4S/5, iPod Touch 4 and iPad2, have digital input docking connectors. This allows manufacturers of external hardware (and their associated software apps) for use with the Apple iOS to optimize the conversion process, thereby ensuring that the device receives an appropriate signal for analysis.

One might think that moving from (1) using the internal microphone as a source to (2) using a separate piece of hardware that houses a dedicated microphone, converter, and power supply may simply add cost without providing significant benefit. Purchasing a dedicated measurement microphone from one manufacturer that connects with a quality piece of conversion/routing hardware from another, which in turn interfaces with a smartphone via the digital input of the docking connector can cost nearly as much as the purchase price of a good Type II SLM. However, there are two advantages to this approach, which include flexibility and data sharing. The separate hardware approach allows the audiologist to choose the complexity of the options, hardware, and other applications. Some educational audiologists may wish to simply have an accurate SLM/reverberation analyzer on their smartphone while others may desire to invest in more sophisticated measurements. A more important advantage is the ability to immediately share measurements with others. It is possible, with the appropriate software, to have your measurements be displayed on another phone in real time. Another, more practical, example of data sharing is sending a screen shot of the metric(s) of interest together with a short narrative explaining the results as a supplement to the full report. Summarizing and sharing data, therefore, becomes streamlined.

Conducting Measurements with a Software Application (app)

Educational audiologists will begin the processes of documenting the acoustical properties of a classroom with apps by considering the hardware that will be used for the measurements. As discussed previously, the tradeoffs of using iPhones or iPads right out of the box in place of a dedicated piece of analysis hardware must be weighed. It is in the opinion of the authors of this article that off the shelf iPhones/iPads can produce adequate acoustical measurements for the purposes of an educational audiologist to share information for the purposes of counseling.

Second, calibration procedures for the chosen software apps must be considered. Simply purchasing, downloading, and installing the app does not ensure adequate preparation to conduct the measurements. It is necessary to calibrate iPhones/iPads and software using a reference SLM. Comparative calibration using a Type II SLM often yields reliable and valid results. Although audiologist will not be able to couple the phone's microphone to a calibration device to document its accuracy and adjust as needed, the alternate procedure of comparing the iPhone's SPL reading with that of a calibrated SLM while measuring a steady noise source, then adjusting the calibration settings in the app's "settings" menu affords fairly accurate calibration results. Instructions for calibrating the app are generally available on the developer's website. The audiologist should be mindful during these measurements that the location of the microphone on iPhones is on the bottom and on iPads is on the top. As a result, calibration and measurements with iPhones may be more accurate if the phone is placed upside down.

If the audiologist has chosen an external microphone/hardware system that connects to the iOS device via the 30-pin/

Lightening dock connector, it can be professionally calibrated and the procedure documented by the third party handling the task. The result of this calibration procedure is a true, Type II sound level meter in a smartphone with the additional capability of being able to send and share the results you have obtained.

Finally, the audiologist will begin measurements using the apps that best suit his or her needs. The following figures will provide an overview of the app bundle AudioTools by Studio Six Digital. The developer of this bundle is an audio professional, having manufactured several other high quality standalone measurement systems. The authors of this article use AudioTools for both iPhone4/4S and iPad2. Figure 1 shows a screen shot from an iPhone with the AudioTools app open and ready for function selection. In Figure 2, the basic analog SLM app was selected; it is reading 44.2 dBA. This measurement represents the sound level in a home with light background music playing. This measurement is and easy to read, store, and share using a screen shot.

While SLM screen shots are clear and somewhat informative, a much more powerful metric would be to measure and graph the SPL over time (i.e., a sound study graph). This tool would provide a useful application directly related to measuring the acoustical aspects of a classroom according to the ANSI S-12.6 2010 Standard. Figure 3 shows a sound study conducted in an unoccupied classroom. It is time stamped, and average sound level (LEQ) is noted in the top, right corner. This screen is a far more illustrative graph to share with educators, audiologists, and parents/staff compared to the simple SLM screen shot as it shows SPL over time, as well as documentation of the date, the time the measurement was taken, and the duration of the measurement. In this example, about 3 minutes, 30 seconds of data was collected, with approximately 1 minute, 18 seconds shown in the screen shot. It is important to note that this particular classroom nearly meets the ANSI standard for unoccupied classrooms of 35 dBA. If several sound studies are made at various locations in the classroom, as recommended by the ANSI standard, and screen shots are taken in each location, a powerful set of data is obtained regarding the unoccupied noise levels of the classroom.

Measures of reverberation time are essential as well. In the bundle of AudioTools apps is an "Impulse Response" app. By measuring impulse response, the audiologist can measure the RT60 of the classroom. There are a several ways to conduct this measurement, and Studio Six Digital has helpful tutorial for in depth instruction. A simple impulse signal, for example a handclap or balloon pop, is usually all that is needed as a signal source to allow the Impulse Response feature to extrapolate accurate RT60 measures for the octave bands specified in the ANSI Standard.

The first step to conduct this measurement is to obtain an Energy Time Curve by recording the impulse noise and the subsequent energy decay over time. Figure 4 shows the Energy Time Curve (ETC) obtained in the same classroom in which the unoccupied sound study data shown in Figure 3 was collected.

Figure 1. AudioTools App selected on iPhone. **Note**: To store and share your measurements, take a screen shot with your iPhone. To do this, hold the "home" button, and press the on/off button on the top. The phone will make a camera shutter sound; the resulting "photo" is now on photo roll.

Figure 2. iPhone with Analog Sound Level Meter App running.

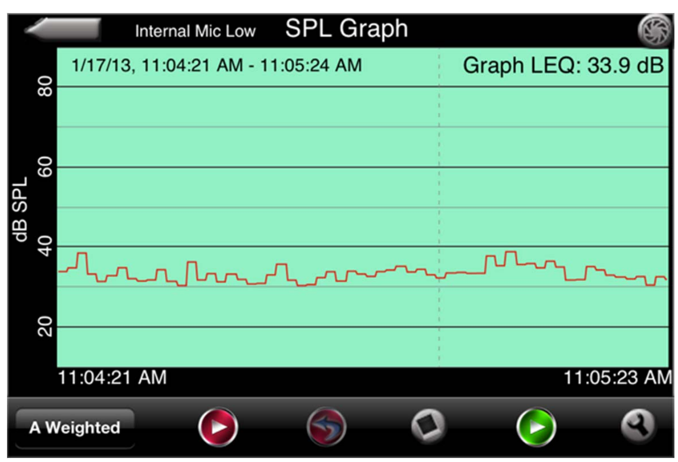

Figure 3. Sound study graph of an unoccupied classroom.

While it does display the energy decay over time within the enclosure, it does not provide the RT60 measures needed for comparison to the ANSI standard.

By clicking on the "ETC" icon in the lower right corner, a menu appears allowing the user to select RT60 measurements. Figure 5 shows the octave band RT60 measurements for the same classroom. Of note is that this is a fairly non-reverberant enclosure. In fact, this room meets the ANSI standard for reverberation. The absence of measures in octave bands at lower frequencies is likely related to the intensity of the impulse sound source, and the decrease in reverberation time as frequency increases is expected.

Using the tools in this app bundle provide the necessary data to compare the acoustical characteristics of a given classroom with the ANSI standard. As shown in the figures, the necessary measurements were obtained accurately, quickly, affordably, and in a manner that allows sharing the information in an email with other audiologists, teachers, and staff members. By simply dragging and dropping the screen shots into the body of an email or into a report, the data can be provided in full color to the desired recipients along with a narrative explanation.

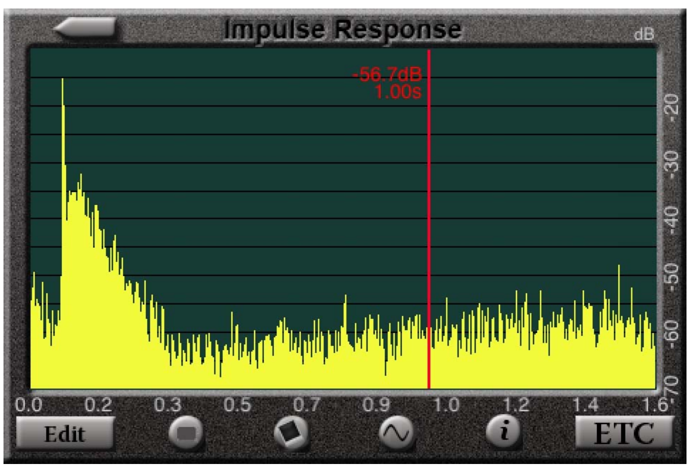

Figure 4. Energy time curve of an unoccupied classroom.

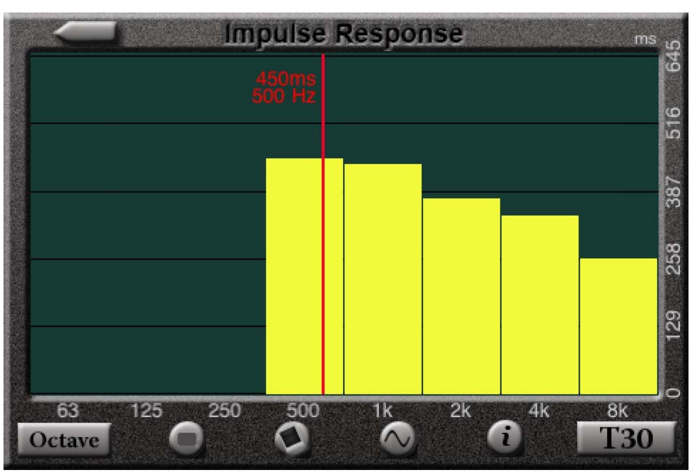

Figure 5. RT60 measures displayed in octave bands.

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Evaluation of (Central) Auditory Processing and Phonological/Phonemic Awareness in 6-Year-Old Children: A Pilot Study to Determine Test Efficiency and Inter-subject Reliability

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It is difficult to test auditory processing in children younger than 7 years of age due to poor inter-subject reliability and the limited attention spans of many younger children. These factors limit the ability of available tests to accurately identify (Central) Auditory Processing Disorder. The primary goal of the current study was to evaluate two tests of auditory processing and a test of phonological/phonemic awareness to determine if they could be administered efficiently to 6-year-olds with acceptable inter-subject reliability and an appropriate level of difficulty (in order for floor and ceiling effects to be avoided). The Pitch Pattern Sequence (PPS) test, a Compressed and Reverberated Speech Test (CRST), and subtests of the Queensland University Inventory of Literacy (QUIL) were given to 29 typically-developing New Zealand 6-year-olds. In general, the tests could be efficiently administered to children. Consistent with the literature, the participants demonstrated variable performance on all tests. Results indicate that it is probable to reliably assess auditory processing in younger children if adjustments are made to the tests to optimize error rates and reduce score variability across test items and lists.

Introduction

There is ongoing discussion and a lack of consensus regarding the exact nature and definition of a (central) auditory processing disorder ((C)APD) and, therefore, the best ways to assess, diagnose, and treat is not fully established (Bellis, 2007). Cacace and McFarland (2005) highlight the importance of evidence-based practice and the need for additional research in the area of (C)APD to ultimately come to a consensus. According to Friel-Patti (1999), disagreement concerning the definition of (C)APD may be due, in part, to the various disciplines attempting to understand it. It is likely that the heterogeneous nature of (C)APD accounts for at least some of the difficulty professionals have had establishing a standard definition. Despite the controversy, a (C)APD consensus group composed of scientists and clinicians concluded that "[C]APD may be broadly defined as a deficit in the processing of information that is specific to the auditory modality" (Jerger & Musiek, 2000, p. 468). More specifically, (C)APD has been described by the American Speech-Language-Hearing Association (ASHA) as "an observed deficiency in one or more" of the following behaviors: sound localization and lateralization, auditory discrimination, auditory pattern recognition, temporal aspects of audition (e.g., temporal ordering), auditory performance with competing signals, and auditory performance with degraded signals" (ASHA, 1996, p. 41). A child with deficiencies of this nature typically exhibits difficulty maintaining auditory attention, following oral directions, retaining information presented orally, and understanding speech in noise or competing messages (Bamiou, Musiek, & Luxon, 2001; Chermak & Musiek, 1992). Teachers or parents who observe these difficulties may assume that the child has difficulty hearing and therefore refer the child for a hearing assessment. If peripheral hearing is found to be normal, (C)APD would be suspected and the evaluation process would begin.

Evaluation of Current Auditory Processing Measures

A multidisciplinary approach for the assessment and diagnosis of (C)APD is recommended (American Academy of Audiology [AAA], 2010; ASHA, 1996; Bamiou et al., 2001; Sharma, Purdy & Kelly, 2009; Witton, 2010). Multidisciplinary assessment enables the professionals involved to collectively determine the impact of the disorder on the person's ability to function in his/her everyday environments and, additionally, helps guide treatment and management decisions (ASHA, 2005). On the basis that (C)APD commonly coexists with speech and/or language disorders, such as specific language impairment (SLI; Bishop, Carlyon, Deeks, & Bishop, 1999) and dyslexia (Ramus, 2004), speech-language pathologists (SLPs) are frequently involved in the assessment of children with suspected (C)APD (ASHA, 2005). DeBonis and Donohue (2004) recommended that SLPs conduct informal assessments of the child's auditory perceptual skills, including auditory discrimination, auditory attention, and auditory memory abilities.

Behavioral measures of auditory processing have a central role in the audiological diagnosis of (C)APD. The following categories of auditory processing tests: sound localization and lateralization, auditory discrimination, auditory pattern recognition, temporal aspects of audition, auditory performance with competing signals, dichotic listening and auditory performance with degraded signals can be assessed behaviorally (AAA, 2010; ASHA, 1996).

Two categories of these tests, specifically temporal processing and monaural low redundancy, are widely used in the assessment of children with suspected (C)APD (Bellis, 2003; Chermak et al., 2007; Emanuel, 2002; Emanuel, Ficca & Korczak, 2011; Krishnamurti, 2007). Because both temporal and monaural low redundancy tests are routinely used in clinical practice for the diagnostic assessment of children aged 7 years and older, these test categories were investigated here to determine their appropriateness for assessing auditory processing in younger children.

Temporal processing. Temporal tests assess the ability of a child to discriminate, sequence, and integrate auditory stimuli (Shinn, 2007). Generally, temporal tests utilize non-speech stimuli, such as tones and clicks (Bellis, 2003). For this reason, temporal tests are useful for the assessment of children for whom English is not their native language (Musiek & Chermak, 1994). Two of the most widely used temporal tests are the Frequency Pattern Test (FPT; Chermak, Silva, Nye, Hasbrouck, & Musiek, 2007; Musiek, 1994) and the Duration Pattern Test (DPT; Bellis, 2006; Chermak et al., 2007; Musiek, 1994). The FPT (Musiek, 1994) is one of several commercially available pitch pattern tests that all require the listener to report back the correct order of high and low pitched tones in a three-tone sequence. The FPT has high test efficiency and has been shown to identify auditory processing difficulties in children with learning difficulties and in persons with cochlear, brainstem, or cerebral lesions (Musiek, 1994). In a survey of 53 certified and/or licensed audiologists, Emanuel (2002) found that a pitch pattern sequence test was the most commonly used temporal test, with 76% of the 25 internet respondents and 61% of the 28 State of Maryland respondents reporting its use in the assessment of auditory processing. In a more recent survey of clinical practice, Emanuel, Ficca and Korczak (2011) reported that 79% of the respondents used a pitch pattern sequence test to assess temporal processing. According to Musiek and Chermak (1994), the FPT should be considered a first-order test for the assessment of auditory processing in children because of the good validity data and high sensitivity of this test. Friberg and McNamara (2010) questioned the validity of the FPT test, but noted its good sensitivity.

Monaural low redundancy. Monaural low-redundancy tests continue to be one of the most popular and widely used tests for evaluating central auditory function (Bellis, 2003; Krishnamurti, 2007). Typically, monaural low-redundancy tests involve the presentation of speech stimuli, which are either degraded by time compression and/or reverberation (Krishnamurti, 2007) or embedded in a competing signal to each ear individually (Bamiou et al., 2001). Tests of this nature reduce some of the extrinsic redundancy of the speech signal to assess a child's ability to fill in missing information and achieve auditory closure (Bellis, 2007). Many audiology clinics are now able to create monaural low-redundancy tests using computer software that can digitally compress, reverberate, or filter speech. Technology of this nature has enabled the removal of accent effects by permitting the recording of speech stimuli using a local native speaker of the language. Tests created using this computer software generate the need for a new set of normative data that is specific to each test.

Evaluation of Phonological/Phonemic Awareness

Phonological/phonemic awareness tests assess a child's awareness of the phonemes, onset and rhyme components, and syllables of spoken language (Larrivee & Catts, 1999; Rvachew, Ohberg, Grawburg & Heyding, 2003). Because (C)APD coexists with dyslexia in some children (ASHA 2005; Bamiou et al., 2001; Ramus, 2004) and phonological/phonemic awareness is a key skill underlying reading ability (Gillon, 2004), the assessment of phonological awareness may assist in the diagnosis and rehabilitation of children with (C)APD.

Phonological/phonemic awareness assessments, such as the Queensland University Inventory of Literacy (QUIL; Dodd, Holm, Orelemans, & McCormick, 1996) and the Test of Auditory Processing Skills (TAPS-3; Martin & Brownell, 2005), may be administered when a child with suspected (C)APD is referred to a SLP. However, the link between performance on these tests and audiological assessments of (central) auditory processing is not known.

Young Children and (Central) Auditory Processing Assessment

The performance of young children on tests of (central) auditory processing is reportedly variable and, for this reason, children under the age of 7 years do not generally undergo full diagnostic evaluations for (C)APD (Bellis, 2003). High inter-subject variability among typically developing children has led to limited normative data for children under the age of 7 years (Musiek & Chermak, 1994). Variations in neuromaturation and attention may account for some of this variability. For some regions of the auditory system, neuromaturation may not be complete until the age of 12 years (Bellis, 2003, Tonnquist-Uhlen, Ponton, Eggermont, Kwong, & Don, 2003). Performance on the FPT is adult-like at age 12 years, but dichotic listening is significantly poorer in 12-year-olds than in adults (Bellis & Ross, 2011). This is not surprising as myelination of corpus callosum axons, important for interhemispheric transfer in dichotic listening tasks, may not be complete until late adolescence (Whitelaw & Yuskow, 2006). This is important given that the axons of the corpus callosum play a significant role in inter-hemispheric integration of auditory information (Whitelaw & Yuskow, 2006).

Despite the variability demonstrated by young school-aged children on (C)APD assessments, delaying auditory processing assessment (and a possible diagnosis) is undesirable. This is especially true since young children are believed to have greater neural plasticity and consequently more potential for functional change (Chermak & Musiek, 1992). Thus, a number of researchers have attempted to identify auditory processing assessments that are appropriate for younger children. Stollman and colleagues (2004b) examined the performance of 4-, 5-, and 6-year-olds on a (central) auditory processing test battery that included a sustained auditory attention test, a dichotic words test, a binaural masking-level difference test, an auditory word discrimination test, and a gap detection test. Additionally, phonemic awareness was assessed using the Lindamood Auditory Conceptualization (LAC) test. They found that, as expected, the performance of 6-year-olds was less variable than the performance of the 4-year-olds on five out of the six tests in the test battery, including tests of phonemic awareness and auditory discrimination (Stollman et al., 2004b).

Keith (2002) tested 6-year-olds on the Time Compressed Sentences Test (TCST) and found that, on average, 6-year-olds were able to repeat speech stimuli at 40% time compression with 93.4% accuracy (SD 8.9%), compared to 7-year-olds who were able to repeat the speech stimuli with 96.7% accuracy (SD 4.2%). The mean percent correct results for the 6- and 7-year-olds did not differ; however, the standard deviation for the 6-year-olds was more than twice the size of that for the 7-year-olds, indicating greater variability in performance for 6-year-olds.

This greater variability of younger school-aged children on tests of auditory processing is also seen in the normative data provided with the AUDiTEC™ Pitch Pattern Sequence (PPS) child version. This pitch pattern test has longer tone durations and longer inter-tone intervals than the more widely used FPT pitch pattern test (Musiek, 1994); hence, it is likely to be more suitable for young children. The mean percent correct score for the 6-year-olds is 82%, whereas for the 7-year-olds the mean percent correct score is 90%. Although these means only differ by 8%, the range of scores for 6-year-old children is much greater at 45-100% than the range for 7-year-olds at 60-100%. Increased variability in the performance of children 6 years of age on the PPS may be due to a lack of understanding for test instructions or insufficient training. The PPS was evaluated in the current study, with the addition of a training phase to see if this would improve inter-subject reliability. A Compressed and Reverberated Speech Test (CRST) and several subtests of a phonological/phonemic awareness assessment were also evaluated. By establishing whether these tests can be efficiently administered, and by determining what adjustments may be necessary to reduce inter-subject variability and ensure an appropriate level of difficulty, it is anticipated that the findings of this pilot study can be used as a basis for the development of a standardized test battery for the assessment of auditory processing in 6-year-old children. Therefore, the primary goal of the current study was to evaluate two tests of auditory processing and a test of phonological/phonemic awareness to determine if they could be administered efficiently and with acceptable inter-subject reliability to 6-year-olds.

Method

Participants

Testing was completed on 16 girls and 13 boys between the ages of 6;0 and 6;11 (years; months) who were recruited from three schools within the Auckland, New Zealand region. The children were recruited based on their age; therefore, their grade level varied across New Zealand's Years 1 and 2 (U.S. grade equivalent: Kindergarten through 2nd grade). The mean age of participants was 6; 6 (SD 3.19). Children were included in the study if they met the following criteria: (1) were typically developing and between the ages of 6;0 and 6;11; (2) did not currently have speech, language, hearing, or learning problems, or a history of speech, language or hearing problems, based on parental report; (3) used English as their main language for communication at home and at school; and (4) exhibited normal hearing and middle ear status at time of testing. Specific information concerning each child's speech, language, and hearing history was obtained from parents and caregivers by way of a short questionnaire. Several children were excluded based on the information provided by their parents or caregivers.

Materials and Procedure

All testing was performed in a quiet room at the participant's school. The level of ambient noise and/or external noise was measured at the beginning of all test sessions and was consistently less than 40 dB SPL. Each participant's hearing status was assessed before the administration of the test battery; participants' outer ear canals were examined via otoscopy. A tympanogram was obtained for each ear using a Grason-Stadler GSI-37 Auto Tymp to ascertain middle ear status. A hearing screening was conducted from octaves 250 to 8000 Hz at 15 dB HL using a Grason-Stadler GSI-61 clinical audiometer. ER-3A insert earphones were utilized for all audiometric and auditory processing assessments. Fifteen children were excluded from the study at this initial stage due to a failure on the middle ear screening (Type B or C tympanograms) or the hearing screening (one or more thresholds > 15 dB HL).

Each participant completed three assessments: the Queensland University Inventory of Literacy (QUIL; Dodd et al., 1996), the AUDiTEC™ PPS child version, and a Compressed and Reverberated Speech Test (CRST) developed at the University of Auckland. The order in which tests were administered was randomized. Each participant completed two, 30-minute test sessions. In the first session, participants underwent all peripheral audiological tests and completed one of the tests of (central) auditory processing or phonological/ phonemic awareness. In the second session, the two remaining assessments were administered.

The QUIL (Dodd et al., 1996) is an assessment tool developed and normed in Australia that is used clinically to assess phonological/phonemic awareness skills of children between the ages of 6 and 12 years. Five subtests of the QUIL (Dodd et al., 1996) were administered, including nonword reading (NWR), syllable identification (SI), spoken rhyme recognition (SRR), phoneme detection (PD), and phoneme manipulation (PM) and were administered in this order in accordance with the QUIL instruction manual (Sharma, Purdy, & Kelly, 2012). These subtests were selected to include stimuli that assess a range of phonological/phonemic awareness skills. Each subtest contains a set of instructions to be verbally presented and a set of practice items that are administered before the presentation of the test items.

The AUDiTEC™ PPS child version is a clinical tool that assesses the ability of young children to identify pitch (frequency) patterns. A pattern of three tones are presented monaurally. Each tone is 500 ms in duration and is either high frequency (H, 1430 Hz) or low frequency (L, 880 Hz). The interval between each tone in the pattern is 300 ms. There are six possible patterns (i.e., high-low-high [HLH], HHL, HLL, LHL, LLH, LHH) and three response modes that the child may use to indicate the perceived pattern, namely humming, verbal labeling, or pointing to a high/low visual. To eliminate tester-bias, the only response mode made available in this study was verbal labeling. Due to concerns about the ability of 6-year-olds to attend to an auditory-based assessment for extended periods of time, a shortened version of the AUDiTEC™ PPS child version was used, with only 15 items per list (one list per ear). Pitch patterns were presented at 60 dB HL through insert earphones via a Grason Stadler GSI-61 clinical audiometer and CD player. All children participated in a training phase prior to presentation of the test items. For the training phase, the clinician told the child what they would be hearing, which was either a high tone (1500 Hz) or a low tone (750 Hz), and then the tone was presented via the GSI-61 audiometer. Once the child could identify the tones in isolation, the clinician would present a two-pattern sequence via the audiometer (e.g., HL or LH) and ask the child to verbally label the pattern. Once the child could successfully label two tone patterns, the clinician would then present three tone patterns (e.g., HHL or LLH) via the audiometer. If a participant was having considerable difficulty identifying the patterns during the training phase, a high/low visual aid was introduced. The visual aid was removed before presentation of test items. Patterns that the child completely reversed (e.g., HLL reported as LHH) were noted for later analysis.

The CRST created for use in this study was composed of two lists of 25 words that were digitally compressed (65%) and reverberated (0.3 s) using Adobe Audition 1.5 software. The words included in each of the lists were taken from the Lexical Neighborhood Test (LNT; Kirk, Pisoni, & Osberger, 1995) easy word list and recorded using a female native New Zealand English speaker. All 60 items of the LNT (Kirk et al., 1995) easy word list were used, and then further divided into two lists of 25 words plus practice items. Each participant was presented with two words that were not compressed or reverberated before listening to practice items that were compressed and reverberated. Participants were instructed to repeat each word and were asked to guess the word if they were unsure of what they had heard. All practice and test items were presented at 60 dB HL through ER3A insert earphones via a GSI-61 clinical audiometer and a CD player. Both phonemic scoring and whole word (right/wrong) scoring were utilized and percent correct scores were calculated.

For the PPS and the CRST, both list order and ear order were counterbalanced and therefore, four list- and ear-order combinations were possible: (1) list one-left ear, list two-right ea; (2) list one-right ear, list two-left ear; (3) list two-left ear, list one-right ear; (4) list two-right ear, list one-left ear. The time taken to complete each of the tests, including instructions, was recorded for each child and rounded to the nearest 30 seconds. The average time taken for the QUIL was 15.5 minutes (SD 2.46; range 10 - 20), the average for the PPS was 10 minutes (SD 2.28; range 6.5 - 14), and the average for the CRST was 9 minutes (SD 2.50; range 5 - 15.5).

Results

Table 1 details the descriptive statistics for all three tests in the battery. Descriptive statistics are presented for both CRST scoring methods (i.e., whole word and phonemic) and for PPS scores, both including and excluding reversals. Performance was variable across and within the tests. In general, the CRST results (when scored phonemically and by whole words) showed the least variability. However, PPS results showed similar variability when reversals were considered correct. Data are presented here with reversals included and excluded for comparison. In general, mean and median test scores agreed within 7% for each of the subtests and lists. However, for the QUIL NWR subtest of the mean percent correct score was almost 17% greater than the median, suggesting that the performance of a few children skewed the data towards a higher average score.

Auditory Processing Tests (Pitch Pattern Sequence and Compressed and Reverberated Speech Test)

List effects. Paired samples t-tests were conducted to determine whether there were significant differences in performance on the two lists of the PPS and the CRST. There was a significant list difference for the PPS when reversals were excluded (Table 2). Participants scored an average of 74.9% (SD 18.6%) on list one and 69.4% (SD 20.5%) on list two. There was no significant difference between PPS lists when reversals were included.

Due to the significant differences in participants' performance on the two PPS lists (excluding reversals), participants' ability to correctly identify the various pitch patterns was investigated. Table 3 displays the distribution of the patterns across the PPS lists and overall percent correct scores for each of the patterns. The LLH pattern was easiest for participants to identify, followed by the HHL pattern. These two patterns occurred more in list one than in list two. The LHL and the LHH patterns were the hardest pattern for participants to identify. Patterns were unevenly distributed between the lists.

Performance across CRST lists was also significantly different for both scoring methods. Participants scored an average of 33.9% (SD 11.9%) and 39.7% (SD 10.9%) for lists one and two (whole words), respectively. Overall, participants scored better when responses were scored phonemically. Average phoneme scores were 54.9% (SD 10.7%) for list one and 66.0% (SD 8.4%) for list two.

Test item effects were investigated because of the CRST list differences. Table 4 presents whole word percent correct values for each of the CRST test items. Several of the words were correctly identified by almost all of the participants (e.g., 'please' and 'just'). Equally, several words were not correctly identified by a single participant (e.g., 'kind' and 'brought').

Ear effects. Possible differences between left-ear and right-ear scores for both the CRST and the PPS were investigated by means of independent t-tests. There was a small right ear advantage for both lists of the PPS and list one of the CRST; however, as illustrated in

Table 1. Descriptive statistics (presented as percent values) for the Queensland University Inventory of Literacy (QUIL), the Pitch Pattern Sequence (PPS) and the Compressed and Reverberated Speech Test (CRST)

Test	Subtest or List	Min.	Max.	Median	Mean	SD
QUIL	NWR	0	95.8	16.7	33.5	32.5
	SI	33.3	100	83.3	78.4	18.3
	SRR	50.0	100	83.3	77.6	17.1
	PD	8.3	91.7	50.0	53.2	22.5
	PM	0	100	60.0	53.8	29.9
PPS – R	List 1	40.0	100	80.0	74.9	18.6
	List 2	26.7	100	73.3	69.4	20.5
PPS + R	List 1	53.3	100	93.3	87.8	12.6
	List 2	66.7	100	86.7	85.5	11.3
CRST WWS	List 1	8.0	52.0	28.0	33.9	11.9
	List 2	20.0	68.0	40.0	39.7	10.9
CRST PS	List 1	32.1	75.2	54.1	54.9	10.7
	List 2	43.4	79.8	66.7	66.0	8.4

Note: WWS (whole word scoring), PS (phonemic scoring), – R (excluding reversals), + R (including reversals), NWR (nonword reading), SI (syllable identification), SRR (spoken rhyme recognition), PD (phoneme detection), PM (phoneme manipulation), SD (standard deviation). The QUIL descriptive statistics were calculated using raw score data rather than standard scores.

Table 2. t-test results for list, ear, reversal, and scoring effects on Pitch Pattern Sequence (PPS) and Compressed and Reverberated Speech Test (CRST) scores

Test	List	Effect	t	Df	Sig. (2-tailed)
PPS		List (- R)	2.74	28	0.011
		List (+ R)	1.63	28	n.s.
	List 1	Ear	-0.36	27	n.s.
	List 2	Ear	-0.92	27	n.s.
	List 1	Reversal	-5.30	28	<0.001
	List 2	Reversal	-5.71	28	<0.001
CRST		List (WWS)	-3.65	28	0.001
		List (PS)	-6.36	28	<0.001
	List 1 (WWS)	Ear	-0.29	27	n.s.
	List 2 (WWS)	Ear	1.74	27	n.s.
	List 1 (PS)	Ear	-0.77	27	n.s.
	List 2 (PS)	Ear	1.93	27	n.s.
	List 1	Scoring	-29.17	28	<0.001
	List 2	Scoring	-20.26	28	<0.001

Note: WWS (whole word scoring); PS (phonemic scoring); - R (excluding reversals); + R (including reversals); n.s. indicates p>.05.

Table 3. Percent correct scores across participants (N=29) for words in both lists of the CRST ordered from highest to lowest

List one		Percent correct	List two		Percent correct
(6)	Truck	82.8	(6)	Please	96.6
(13)	Friend	75.9	(15)	Just	96.6
(19)	Wash	72.4	(25)	Watch	89.7
(12)	School	58.6	(12)	Seven	89.7
(23)	Little	55.2	(21)	Which	86.2
(11)	Finger	55.2	(20)	Food	69.0
(7)	Children	48.3	(5)	Pocket	58.6
(4)	Stand	37.9	(14)	Street	51.7
(15)	Lipstick	37.9	(2)	First	51.7
(10)	Broke	34.5	(9)	Don't	31.0
(18)	Juice	31	(17)	Shoelace	31.0
(24)	Snake	27.6	(8)	Puzzle	27.6
(25)	Open	24.1	(22)	Space	27.6
(17)	Monkey	24.1	(23)	Black	27.6
(22)	Draw	20.7	(24)	Its	27.6
(20)	Ducks	17.2	(13)	Eggs	27.6
(21)	Myself	17.2	(7)	Help	24.1
(8)	Cried	13.8	(4)	Stay	24.1
(16)	Give	13.8	(18)	Wonder	24.1
(9)	Farm	6.9	(16)	Grey	10.3
(2)	Airplane	3.4	(3)	String	10.3
(3)	Brown	3.4	(10)	Scribble	6.9
(1)	Kind	0	(1)	Green	3.4
(14)	Thinks	0	(11)	Door	0
(5)	Broken	0	(19)	Brought	0

Note: Numbers in parentheses indicate test item numbers.

Table 4. Distribution of pitch patterns (30) across the lists of the Pitch Pattern Sequence (PPS) and percent correct scores across participants (N=29) for each of the pitch patterns

	HLL	LHH	LHL	HLH	HHL	LLH
List 1	1	1	2	4	4	3
List 2	1	3	2	4	3	2
Percent correct	65.5	64.7	55.2	71.1	79.3	82.8

Note: HLL (high-low-low), LHH (low-high-high), LHL (low-high-low), HLH (high-low-high), HHL (high-high-low), LLH (low-low-high).

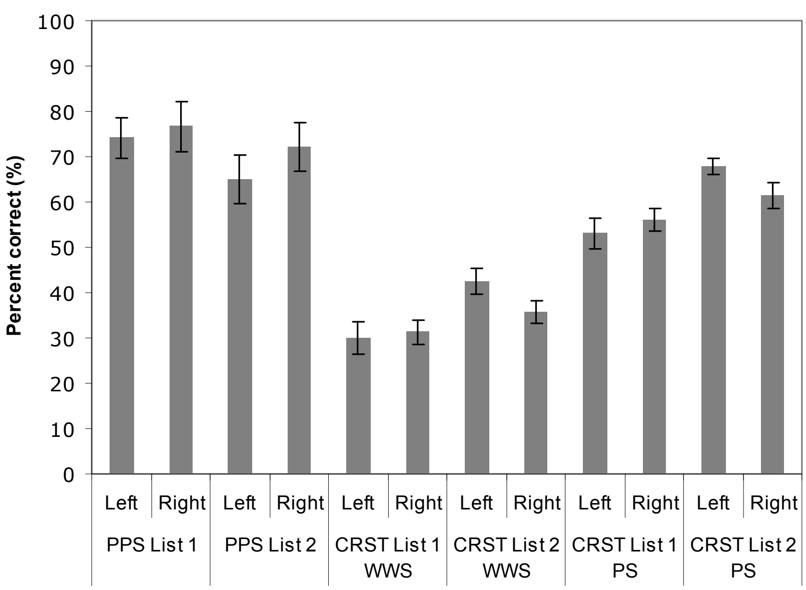

Figure 1. Mean percent correct scores for list one and two of the Pitch Pattern Sequence (PPS; excluding reversals) and the Compressed and Reverberated Speech Test (CRST) according to the ear in which the lists were presented. Mean percent correct scores for both scoring methods of the CRST are presented. Error bars indicate ±1 standard error.

Figure 1 and Table 2, no significant differences were found between the participants' left- and right-ear performance on either list of the PPS or CRST.

Scoring effects. A paired samples *t*-test was conducted to determine whether mean list scores for the PPS were significantly different when reversals were added to the final score. Both list one and list two scores were significantly better when reversals were considered correct and included in the final score (Table 2).

The two lists of the CRST were scored phonemically and by whole words. Paired samples *t*-tests showed a significant difference between mean percent correct scores according to scoring method for both CRST lists (see Table 2). For list one, the average whole words percent correct score was 33.9% (SD 11.9%) and the mean phonemic percent correct score was 54.9% (SD 10.7%). For list two the means were slightly higher. The average whole words percent correct score was 39.7% (SD 10.9%) and the mean phonemic percent correct score was 66% (SD 8.4%).

Phonological Assessment (Queensland Inventory of Literacy)

The QUIL raw scores were converted to standard scores using the normative data provided in the QUIL test manual. As these normative data are grouped according to school year (e.g., grade one, grade two etc.), the data obtained in this study were not directly comparable to the normative data of the QUIL. The mean age of the grade one QUIL sample was 6; 3 (years; months) and the mean age of the grade two QUIL sample was 7; 2. Neither grade level sample age was identical to the mean age (6; 6) of the sample in the current study, and, hence, the raw scores were converted to standard scores using both grades one and two normative data, depending on the age of the individual child. The QUIL standard score mean was 10 (SD 3).

As shown in Figure 2 participants performed better than the QUIL normative data for the grade one sample, but poorer than the grade two sample on all five subtests. Overall, participants performed best on the NWR and the PM subtests. However, the range of scores for these subtests, particularly NWR, was relatively large. Participants performed poorest on the SRR and PD subtests and these subtests both had a large range of scores. Performance was most consistent for the SI subtest.

Discussion

All children were able to complete all tests and the average time for each test was approximately 10-15 minutes including instruction and practice. Thus, in general, the QUIL, PPS, and CRST can be efficiently administered to 6-year-old children. Performance was quite variable, however, and several modifications are recommended to reduce variability between items, lists, and participants.

Pitch Pattern Sequence

Participants in the current study were less variable on this assessment (when reversals were included as a correct response) than the children in the AUDiTEC™ PPS 6-year-old sample. Thus, the training phase may have enhanced inter-subject reliability. Participants showed no ear effects on the PPS, but a small right ear advantage (REA) was noted. This is consistent with other data obtained for pitch pattern tests (Bellis, 2003; Kelly, 2007). Kelly (2007) found a slight REA in the FPT for the youngest age group (7- and 8-year-olds).

A list effect was observed when reversals were excluded. The difference in distribution of the pitch patterns across the lists and variations in pattern difficulty are likely to have caused this list difference. Two patterns were clearly easier for the participants to identify, namely HHL and LLH. On the basis that the first two tonal stimuli are identical (i.e., HH and LL) in both of these patterns, memory may have had an impact on the participants' performance. Recall of the first two stimuli in these patterns would be reinforced by repetition of the same tonal stimulus. The memory trace for the high or low tone would be strengthened by the repetition of the stimulus (Haenschel, Vernon, Dwivedi, Gruzelier, & Baldeweg, 2005), allowing the participants to confirm their judgment of the first tone and more easily distinguish the first two tones from the final tone.

There was no list effect when reversals were scored as correct. A possible explanation for this is that participants reversed several of the harder items and when these were included in the final score, the difference between the list means was not as great. In order to eliminate list differences, future PPS lists should contain equal numbers of each pattern in lists. Reversals should be recorded so that results can be compared with and without reversals in typically developing children versus children with suspected (C) APD to determine the diagnostic utility of the scoring methods for this population.

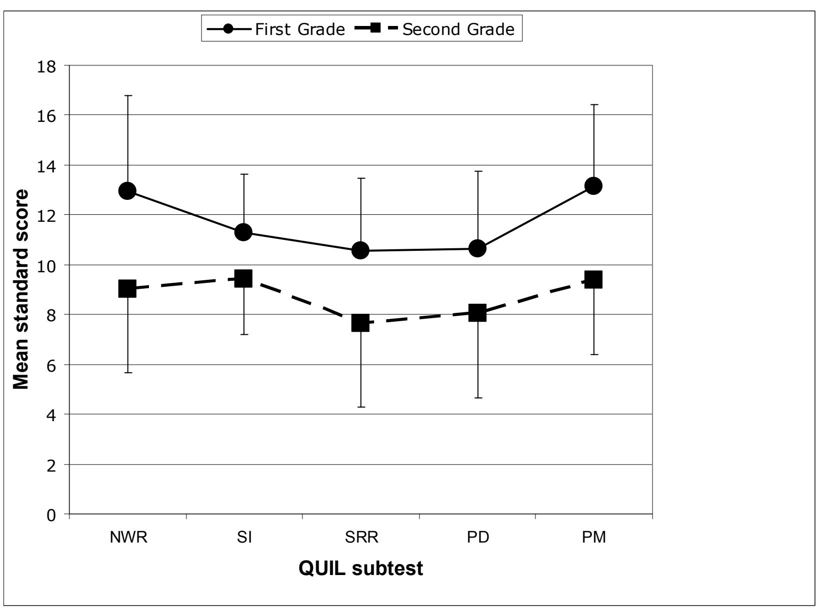

Figure 2. Mean standard scores for the nonword reading (NWR), syllable identification (SI), spoken rhyme recognition (SRR), phoneme detection (PD), and phoneme manipulation (PM) subtests of the QUIL. The upper line shows the mean standard score calculated using the grade one standardization data, and the lower line shows the mean standard scores calculated using the grade two standardization data. Error bars indicate ±1 standard deviation.

Compressed and Reverberated Speech Test

Performance was least variable across participants on the CRST and variability of scores was similar for phonemic and whole word scoring. As anticipated, scores were higher when calculated using phonemic scoring, but this was a difficult task. While phonemic scoring gives credit to an examinee for each phoneme repeated correctly (rather than simply marking something correct versus incorrect) it requires that the clinician be experienced in phonemic scoring. Unfortunately, the words used to create the CRST were not equally identifiable when compressed and reverberated due to the distortion that occurs when a word is digitally compressed and reverberated. The LNT easy words used in this assessment are words with a high frequency but few lexical neighbors (i.e., words that differ by only one phoneme; Kirk et al., 1995). According to the British National Corpus the test words vary in frequency from 6 to

1632 per million words (Leech, Rayson, & Wilson, 2001). Words in the test lists that had a greater frequency, based on the British National Corpus, were not necessarily easier for the participants to identify, and therefore lexical frequency does not appear to have had a substantial impact on the performance. The acoustic properties of the sounds contained within the words are likely to have had the most significant impact on how identifiable the words were once they were compressed and reverberated. However, determining the impact of acoustic distortion versus lexical frequency on word accuracy is difficult. In general, the words that were correctly identified contained fricatives (e.g., 's'), affricates (e.g., 'j'), liquids (e.g., 'r'), and glides (e.g., 'w'). It may be that particular sounds are more susceptible to the effects of distortion (compression/reverberation) than other words. Future use of this assessment should be performed using lists better matched for word difficulty after the words are compressed and reverberated.

Queensland University Inventory of Literacy

The NWR subtest was the most difficult of the QUIL subtests and this subtest also demonstrated the greatest variance. Participants demonstrated the highest scores and the least variability on the SI and SRR subtests. The variability participants demonstrated across QUIL subtests may be due to two factors. The first factor is variation in reading instruction. A phonics approach to reading instruction involves the teaching of letter sounds to facilitate the decoding of unfamiliar words (Vellutino, 1991). In contrast, whole word and whole language approaches to reading encourage children to identify words as a whole and use the immediate context of an unfamiliar word to facilitate meaning (Vellutino, 1991). Participants who learned to read primarily or solely via a phonics approach may be more successful at thinking about the sounds and sound parts that make up words than those who have taught to read by means of a whole word or a whole language approach. Children in New Zealand may be taught using one or both of these approaches. Figure 2 shows that, if grade two norms are used, performance was close to the norm and was reasonably consistent across PD, SRR, and SI subtests. This suggests that these skills may be less influenced by variations in reading instruction between children. A reduced set of QUIL assessments including these three subtests would assess a range of phonological awareness skills with acceptable inter-subject variability, at least for the sample of children in the current study.

Summary

The accurate identification of children with (C)APD requires a multi-professional approach (Witton, 2010). Unfortunately, the diagnosis of pure (C)APD is rare; therefore, it is important to incorporate additional tests of speech and/or language in the comprehensive evaluation for (C)APD (Sharma, Purdy & Kelly, 2009; Witton, 2010). Due to the complexity of the brain and the global impact of developmental disorders, this study included tests of both auditory and phonological/phonemic processing in the evaluation for (C)APD.

The performance of 29 typically-developing 6-year-olds on an auditory and phonological/phonemic processing test battery was examined. The test battery consisted of the PPS, CRST, and QUIL. With some modifications, all three tests can be efficiently administered to 6-year-old children. For the PPS, the lists should be modified so that they contain equal numbers of each type of pattern. The lists in the CRST should be reorganized so that they consist of words with more evenly matched difficulty. Because of the influence of literacy education on phonological/phonemic awareness results, normative results for QUIL subtests are likely to vary between educational systems and hence more research is needed to establish the link between auditory processing and phonological awareness in young children. The sample size of the current study was relatively small, yet comparable to those of several other studies examining the performance of young children on tests of auditory processing (Keith, 2002; Stollman et al., 2004a; Stollman et al., 2004b). Further research is needed to establish the inter-subject and test-retest reliability of tests of auditory processing in large groups of younger children (less than 7 years of age). Once reliable measures are established, the sensitivity of these measures to (C)APD should be assessed.

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Speech Recognition in Noise by Children with Hearing Loss as a Function of Signal-to-Noise Ratio

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As part of a larger study, the speech recognition in continuous and interrupted noise was measured for ten children with moderate-to-severe sensorineural hearing loss (HL), ages 6 to 16 years, at varying signal-to-noise ratios (SNRs). Children with bilateral amplification received 10 sentences at each of six SNRs with the 60 dBA noise at 180 degrees azimuth and the speech at 0 degrees azimuth. Sentences were randomly selected from a corpus of 1500 sentences taken from seven thematic categories. The continuous and interrupted speech-shaped noise was filtered to match the long-term average spectrum of the sentences. The average performance-intensity (PI) functions for the interrupted and continuous noise conditions were not significantly different. Children with HL received limited benefit from the interruptions in the noise and therefore might benefit from auditory training designed to take advantage of the silent intervals in noise. Based on the average PI function, an appropriate SNR to begin auditory training would be 6 dB.

Introduction

Even though the quality of hearing-assistive technology (HAT) has greatly improved access to auditory information, pediatric hearing aid users still have difficulty understanding speech in noise. While the advancements in HAT have been extremely successful in providing better access to auditory information in noisy environments, the devices cannot surpass the auditory capacity of the individual with hearing loss (HL). Auditory capacity refers to the ability to process auditory information in conjunction with cognitive resources with auditory sensitivity and resolution being key factors (Boothroyd, 1997). Thus, interventions, such as auditory training coupled with HAT, are important in providing children with HL a comprehensive aural habilitation plan. Recently, there is renewed interest in auditory training as a method to improve speech perception abilities, especially in noise. However, there is a paucity of research related to the effectiveness of auditory training in noise for children with HL. There is also a lack of appropriate intervention materials designed to improve speech recognition in noise for children with HL. Materials that are appropriate for children with normal hearing may not account for differences in the language and audibility levels of children with HL. Therefore, two issues should be addressed before implementing auditory training in noise. First, the vocabulary should be familiar and appropriate so there is no confound with the varying language levels of children with HL. Second, the noise level for auditory training should be equal in difficulty for interrupted and continuous noise conditions. In order to determine if auditory training in interrupted and continuous noise could be beneficial, it is necessary to develop a performance-intensity (PI) function for each noise type by children with HL.

Auditory training is an area of interest for researchers and clinicians who seek to improve the listening and communication skills of individuals with HL. Recently, computer-based auditory training (CBAT) programs have become a popular method to provide cost-effective and reliable intervention. The emergence of CBAT programs, such as Listening and Communication Enhancement (LACE), has provided some evidence in support of training in noise for adults with HL (Sweetow & Sabes, 2006). However, most commercially-available CBAT programs for children are designed to address remediation of language disorders (Clendon, Flynn, & Coombes, 2003; Hayes, Warrier, Nicol, Zecker, & Kraus, 2003; Pokorni, Worthington, & Jamison, 2004; Zwolan, Connor, & Kileny, 2000) and are not specifically designed to improve the hearing abilities of individuals with HL. Although some programs are promoted for pediatric hearing aid users, there is no evidence regarding their effectiveness. In three studies, children with cochlear implants improved in speech and language following CBAT training (Clendon, et al., 2003; Schopmeyer, Mellon, Dobaj, Grant, & Niparko, 2000; Zwolan, et al., 2000). Several studies indicated that frequent users of the CBAT programs receive more benefit (Pokorni, et al., 2004; Zwolan, et al., 2000). However, there has not been any clear evidence that one of the currently commercially-available programs is significantly more effective than the others. Several studies have indicated the quantity of time spent practicing skills using CBAT is associated with amount of benefit received from the program (Pokorni, et al., 2004; Zwolan, et al., 2000). Limitations in the CBAT literature are the small sample sizes, lack of follow-up assessments, and duration of training. While there is no evidence of CBAT in noise as an effective intervention to improve speech perception in noise for children with HL there is some evidence for adults with HL.

Speech recognition in noise is a complex process that is dependent on the detection of spectrotemporal cues in the target signal. Several researchers suggest that redundancy of the speech signal, along with contextual and indexical information, facilitates the understanding of speech in adverse listening conditions (Assmann & Summerfield, 2004; Cooke, 2003, 2006; Li & Loizou, 2007, 2009). Numerous studies indicate that glimpsing is one strategy by which speech in noise is understood (Assmann & Summerfield, 1994, 2004; Cooke, 2003, 2006; Culling & Darwin, 1993; Li & Loizou, 2007, 2009; Miller & Licklider, 1950). In the case of children and individuals with hearing impairment, researchers still have a limited understanding of which cues are most beneficial to perceive speech in noise. Evidence suggests that children with HL may utilize listening strategies to understand speech in noisy environments differently from peers with normal hearing and adults with HL (Eisenberg, Shannon, Martinez, Wygonski, & Boothroyd, 2000; Jerger, 2007; Stuart, 2005).

Several researchers believe that listening in interrupted noise may provide additional information on how individuals with and without hearing impairment understand speech in challenging environments (Bacon, Opie, & Montoya, 1998; Jin & Nelson, 2010; Miller & Licklider, 1950; Stuart & Phillips, 1996; Wilson et al., 2010). For example, previous research with adults and children with normal hearing indicates that speech recognition in interrupted noise may yield better thresholds than in continuous noise at the same signal-to-noise ratio (SNR) (Stuart, 2005; Stuart & Phillips, 1996). These results likely relate to the silent intervals in the interrupted noise, which allow listeners to access additional acoustic and linguistic cues that aid in speech understanding in noise. The perceptual advantage increases with age for children with normal hearing and does not reach adult-like levels until around age 11 years (Stuart, 2005). Currently, there is no information regarding the differential between speech recognition in interrupted and continuous noise for children with HL. It is possible that children with HL may follow the same developmental time course as their peers with normal hearing with a slight delay. Alternatively, the presence of hearing impairment may severely disrupt auditory development such that they do not experience any perceptual advantage in interrupted noise. Typically, adults with HL will experience a reduced release from masking compared to individuals with normal hearing in interrupted noise (Jin & Nelson, 2010; Stuart & Phillips, 1996; Wilson, et al., 2010). For the purpose of this study, release from masking refers to the difference between continuous and interrupted noise word recognition scores. Because of the paucity of information on the speech recognition in interrupted noise for children with HL, it is important to establish what perceptual advantage, if any, they receive. This is necessary to design auditory training programs in interrupted and continuous noise at comparable difficulty levels.

Rationale

Auditory training in noise could be an effective method to enhance listening strategies, such as glimpsing, and to improve speech recognition in noise skills for children and adults with hearing impairment. Specifically, computer-based auditory training could provide a consistent and reliable method to provide delivery of services at home or school. Changes in auditory plasticity through auditory training are supported by perceptual learning and electrophysiology studies (Karni & Sagi, 1993; Kilgard & Merzenich, 1998; Kilgard, Vazquez, Engineer, & Pandya, 2007; Kraus et al., 1995; Recanzone, Schreiner, & Merzenich, 1993; Tremblay & Kraus, 2002; Tremblay, Kraus, Carrell, & McGee, 1997). Evidence also supports the use of noise in the training environment (Burk & Humes, 2007, 2008; Burk, Humes, Amos, & Strauser, 2006; Hayes, et al., 2003; Humes, Burk, Strauser, & Kinney, 2009; Kilgard, et al., 2007; Moucha, Pandya, Engineer, Rathbun, & Kilgard, 2005; Warrier, Johnson, Hayes, Nicol, & Kraus, 2004). Furthermore a well-developed auditory training in noise program could be beneficial in improving speech recognition abilities of children with hearing impairment because their daily lives are filled with noise, and additional hearing assistive devices (i.e. FM systems) are not always available. Therefore, auditory training methods that focus on developing skills to improve speech understanding in noise are vital. Currently, there is limited information regarding auditory training in noise for children with hearing impairment. Evidence suggests that interrupted noise may provide more opportunities than continuous noise to access spectrotemporal cues, which may lead to improved speech recognition in noise abilities over time.

The first step to developing this type of auditory-training program is to establish parameters for presentation level and step size. Determining the starting SNR level is important to ensure audibility and similar difficulty for interrupted and continuous noise, and the step size will determine appropriate changes of SNR for each noise condition. When these parameters are established, it will be possible to a PI function based on speech recognition in interrupted versus continuous noise at different SNRs by children with HL. These results would then be useful for developing pediatric auditory-training protocols for a larger investigation of the benefits of auditory training in noise in children with HL (Sullivan, Thibodeau, & Assmann, In Press). More specifically, the slopes of the PI functions in interrupted and continuous noise would be used to establish easy, medium, and difficult levels for systematic auditory training. As a result, the purpose of this study was to determine the PI functions for speech recognition in noise by children with moderate-to-severe, sensorineural HL in order to establish the parameters to be used in auditory training.

Methods

Participants

Ten children, ages 6 to 16 (mean age 9 years, 6 months), were recruited from school districts in Texas and Louisiana. All children had moderate-to-severe sensorineural HL with at least one year of experience with bilateral hearing aids. The configuration of HL was similar between ears and participants. The children were all native English speakers and had no history of neurological impairments and/or auditory neuropathy according to case history. Table 1 provides additional demographic information about the participants. No child was excluded based on gender, ethnic, or racial group. All of the participants were administered the OWLS: Listening Comprehension Scale and Oral Expression Scale to assess receptive and expressive language levels (Carrow-Woolfolk, 1996). All participants had language levels within 2 years of their chronological age at the time of testing. All testing was conducted with the child's personal hearing aids at user settings following a listening check and visual inspection to verify function. Digital hearing aids were worn by all participants during all testing.

Speech stimuli

A young, native American-English speaking adult female with normal hearing recorded a corpus of 1500 sentences from which a random sample was selected to comprise six unique lists of 10 sentences. In order to reflect a typical classroom environment, we selected a female talker for the stimuli. Because vocabulary and language can be an issue for children with HL, we developed our stimuli to reflect common words that all children should be familiar with and to have enough material for auditory training. Each sentence began with a carrier phrase followed by an adjective, adjective, and a noun; or possessive noun, adjective, and noun (i.e., *He saw three green bears*). There were six themed categories of 216 sentences each, and one category with 125 sentences as shown in Table 2. The final three keywords of each sentence were monosyllabic to increase homogeneity of the stimuli within the category. As shown in Figure 1, the sentences were recorded in a double-walled Wenger sound-treated booth using a desktop microphone (Condenser Shure model SM94). A pre-amplifier was connected to the microphone, and the output was delivered to the amplifier module of the Tucker Davis Technologies (TDT) System 3. The signal from the TDT system was digitized at a sampling rate of 48,828 Hz by a computer using a MATLAB program. The talker was seated with the microphone approximately 8 inches from her mouth.

Each sentence was recorded with a relatively slow, clear speaking rate and was approximately 4 seconds in duration. Sentence prompts were presented at the top portion of the computer monitor every 4 seconds throughout each block. The lower portion of the computer screen displayed a VU meter to monitor vocal intensity during recording. The talker was instructed to monitor her speech and keep the marker in the middle of the scale. After the stimuli were edited for errors and extraneous noise, they were scaled to an equal RMS level.

Table 1. Demographic Information

Participant	Gender	Age	PTA-Left dBHL	PTA-Right dBHL
S1	M	6	76	63
S2	F	7	82	83
S3	F	7	57	55
S4	F	8	55	50
S4	M	8	55	57
S5	M	9	43	48.3
S6	F	10	73	70
S8	M	10	43	38
S9	M	15	56	45
S10	F	16	45	38
Mean			59	55
SD			14.00	14.23

Note. PTA= Pure tone average, SD=Standard Deviation, M=Male, F=female.

Table 2. Template for Themed Categories and Sentence Totals

Theme Categories	Total Number of Sentences	Template
Transportation	216	We saw *number + color + vehicle*
House	125	Her house has a + *adjective + color + object*
Food I	216	We ate *number + color + food*
Mall	216	Mother brought *proper name+ color + clothing*
Zoo	216	He saw + *numbers+ colors+ animals*
Food II	216	Grandmother gave *proper name + color + food*
Toys	216	I saw *proper name('s)+ number + toy*

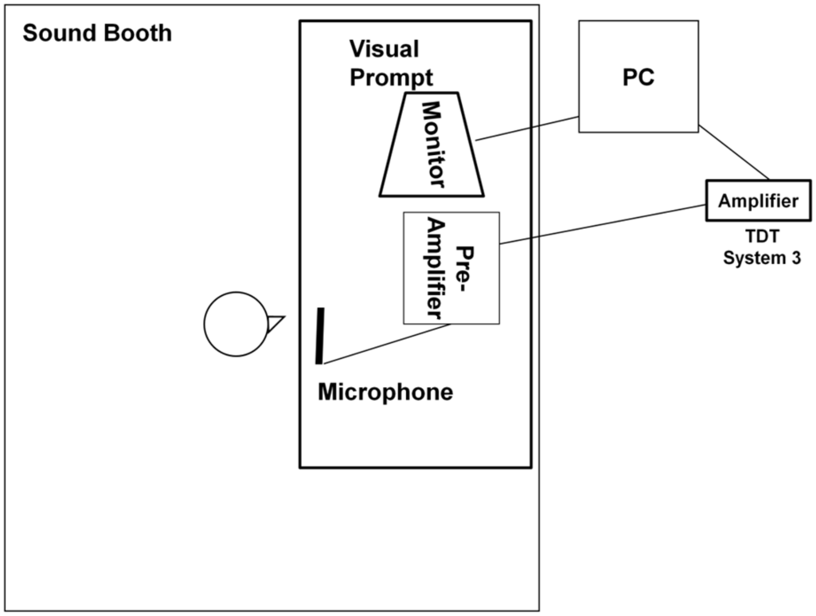

Figure 1. Arrangement for digital recording of speech stimuli.

Noise Stimuli

Continuous speech-shaped noise was generated from random samples of digital speech and shaped according to the long-term average speech spectrum of the female talker. To create the interrupted noise, the continuous speech-shaped noise was interrupted randomly with 5 to 95 ms silent intervals and a duty cycle of .50 using a MATLAB program (Stuart, 2005, 2008; Stuart & Phillips, 1996). Random interruptions of 5 to 95 ms were used to provide an ecologically valid listening environment as the number and duration of interruptions varies in the real world.

Mixing of Speech and Noise

The noise and speech were recorded on separate channels. The continuous speech-shaped noise was used to calibrate each speaker prior to testing. The RMS level of the noise was equivalent to the average RMS level of the sentences. The noise remained on between sentences and was fixed at 60 dBA as measured by a sound-level meter (Radio Shack Model 33-2055) at the location of the listener's head. The lists of sentences were scaled in 6-dB steps in MATLAB and then organized into six tracks at the following SNRs: -18, -12,-6, 0, 6, and 12 dB. Two compact discs with six tracks each were recorded for the interrupted and continuous noise conditions. For example, at -12 dB SNR, the noise remained at 60 dBA while speech was at 48 dBA.

Equipment and Procedure for Performance-Intensity (PI) Function

For the PI function, children were tested in a quiet room at their school where the ambient noise ranged from 40 to 50 dBA as measured by a head-level sound level meter at their seat. A Sony CMT-BX20i 50w Micro Hi-Fi Shelf System with two detachable speakers was used to present the stimuli one meter from the child's seated position as shown in Figure 2. The speech was presented at 0 degrees azimuth while noise was presented at 180 degrees azimuth. A practice list was presented in quiet to familiarize the child with the vocabulary and procedure. One list of ten sentences was presented in interrupted and continuous noise at each of the following dB SNRs: -18,-12,-6, 0, 6, and 12. The sequence of SNR presentations was randomized across noise conditions, which were counterbalanced among participants. The child gave a verbal response, and the final three keywords were scored to yield a percent correct score for each SNR level.

Results

Individual Results

Figure 3 shows the individual word-recognition performance scores as a function of SNR in interrupted and continuous noise. In the interrupted condition only, three children were able to take advantage of the interruptions at -18 SNR with word recognition performance ranging from 10% to 40% compared to 0% to 3% performance in the continuous condition. The greatest variability for listening in the interrupted noise was at the -6 dB SNR (*M*= 32%, *SD*= 28), and the least variability was at the highest SNR, 12 dB (*M*= 92%, *SD*= 13). The SNR with the greatest variability for listening in the continuous noise was at 0 dB (*M*= 53%, *SD*= 35), and the SNR for the least variability was at -18 dB (*M*= .30%, *SD*=

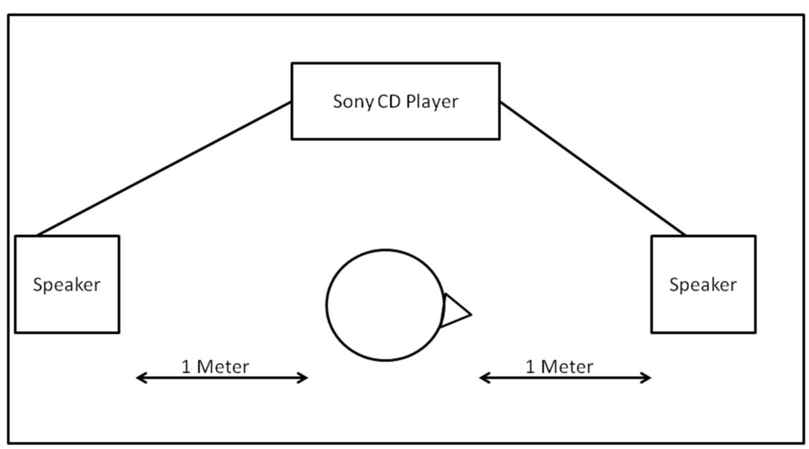

Figure 2. Arrangement for evaluating speech recognition in noise with children with hearing loss.

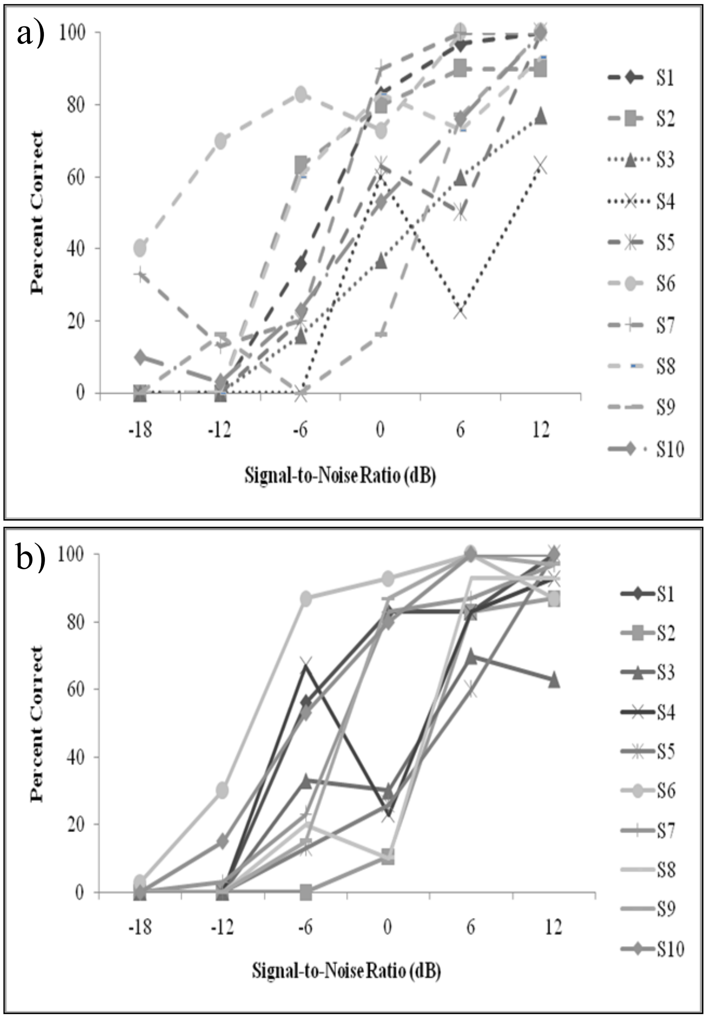

Figure 3. Individual word-recognition percent correct scores across signal-to-noise ratios plotted as a function of participant number for the a) interrupted noise condition and b) continuous noise condition. Some data points overlap.

.95). Participant S4, the youngest participant, demonstrated non-monotonic functions for both interrupted and continuous noise.

Group Results

Figure 4 illustrates the mean performance-intensity (PI) function for 10 children with moderate-to-severe HL in interrupted and continuous noise. Percent correct scores for word recognition in interrupted and continuous noise were plotted as a function of SNR. Third-order polynomial regression lines were fit to determine the 80% word-recognition performance level in interrupted (R^2=.993) and continuous noise (R^2=.998).

Determining Appropriate Performance Level

The PI function can be used to determine a starting level for auditory training for children with these stimuli. To start training at a relatively easy level, the 80% word-recognition performance level was selected. Using the corresponding equations shown in Figure 4, the 80% performance level for the interrupted noise was 6.73 dB SNR and for the continuous noise was 6.41 dB SNR. Because the levels were similar, the recommended initial training level is 6 dB SNR in both noise conditions for auditory training with these sentence stimuli.

Discussion

The purpose of this study was to determine a PI function in interrupted and continuous noise for children with moderate-to-severe hearing impairment ages 6 to 16 years old that would guide the development of a larger computer-based auditory training program. Word-recognition performance in interrupted and continuous noise was evaluated at the following SNR: -18, -12, -6, 0, 6, and 12 dB. The release from masking, as shown in Figure 5, was calculated by subtracting word-recognition scores in interrupted noise from scores in continuous noise at the same SNR. The children with HL in this study demonstrated limited release from masking as shown in Figure 5. In the current study, the average release from masking was about 3% at 0 dB SNR on these open-set simple sentences for children with HL. While it is difficult to make a direct comparison between the current study and the findings of Stuart (2005), because differences in hearing status, age, stimuli type, and sample size, it is important to recognize that children with normal hearing demonstrate a release from masking when comparing performance in continuous and interrupted noise (Stuart, 2005). In addition, this release

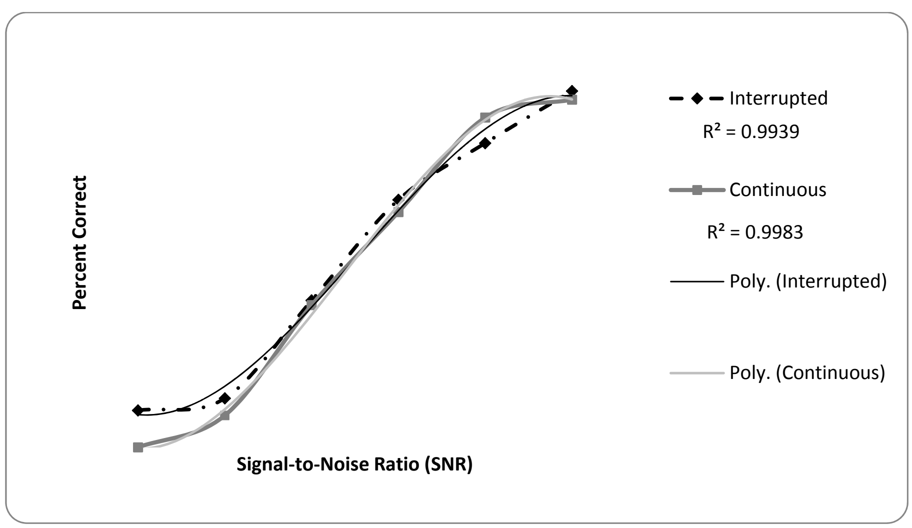

Figure 4. Mean performance-intensity functions in interrupted and continuous noise. Poly = 3rd order Polynomial regression line for the average interrupted and continuous conditions. Equation for the interrupted function $y = -1.339x^3 + 14.22x^2 - 26.34x + 21.46$; Equation for the continuous function $y = -1.626x^3 + 16.49x^2 - 28.46x + 13.23$.

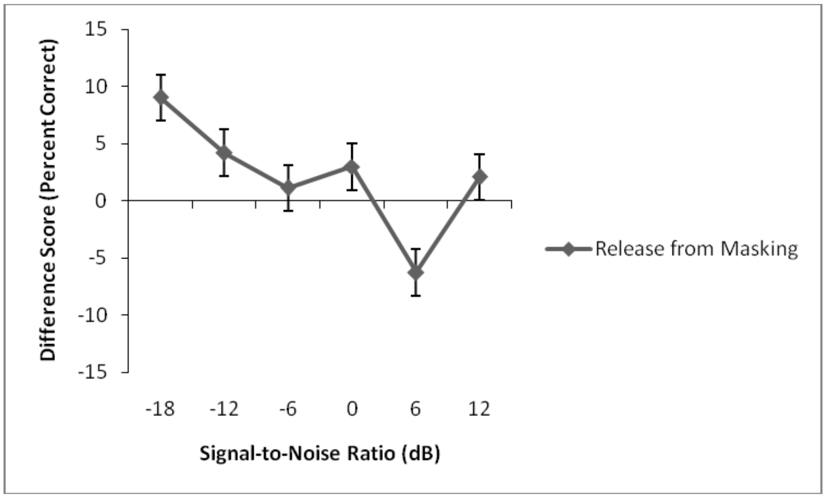

Figure 5. Mean release from masking (i.e. interrupted noise minus continuous noise score) as a function of signal-to-noise ratio. Error bars indicate standard errors.

from masking increases with age. According to Stuart (2005), children with normal hearing, ages 8 to 9 years old, experience about a 9% release from masking at 0 dB SNR on open-set word stimuli.

As expected, there was high variability associated with speech recognition in noise by children with hearing impairment (Finitzo-Hieber & Tillman, 1978). For example, Participant S4, the youngest participant, demonstrated inconsistent word-recognition performance across SNR conditions for both noise conditions. This is especially evident in the 6-dB SNR interrupted noise condition where S4 scored 23% while the mean word-recognition score was 75%. Overall, there was little difference between the slopes of the interrupted and continuous noise PI functions. However, the variability across participants suggests that further examination of the difference in speech recognition in interrupted and continuous noise for children with hearing impairment is needed. Therefore, research with a larger sample size is necessary before any conclusions can be reached regarding the amount of release from masking experienced by children with HL and the auditory perception processes involved in speech perception in noise. However, the parameters for the starting SNR level (6 dB) and adaptive-step size (6 dB) determined from this sample may be useful guides in the development of auditory training programs for children with HL.

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Comparison of Pure-Tone and Distortion Product Otoacoustic Emission Screenings in School-Age Children

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The purpose of this study was to compare the outcome of a distortion product otoacoustic emission (DPOAE) screening to the outcome of a pure-tone hearing screening for school-age children. Participants included 565 children in kindergarten through second grade in central Arkansas. Data were analyzed on a total of 547 participants. A McNemar Chi-square test [χ^2 (1, N=547) =2.06; *p*=.151)] revealed there was not a statistically significant difference between the rates of identification for the DPOAE and pure-tone screenings. Four hundred and seven (74%) participants had the same outcome on both screening measures, either pass (N=369) or refer (N=38). However, 140 (26%) of the participants were classified as "pass" or "refer" by one of the screening measures, but not both. Although the majority of these children (74%) obtained the same results on both screening measures, a relatively large percentage (26%) had differing results. Therefore, it was unclear whether those children had hearing sensitivity that was of concern, or whether one or both of those screening measures would have indicated a large over-referral rate. The analyses revealed these screening measures are not interchangeable, and the two may offer unique contributions to the identification of individuals who should be referred for further diagnostic testing. Without a follow-up diagnostic test, the exact relationship between the two screening measures could not be determined. Further testing using a complete diagnostic evaluation (i.e., otoscopy, immittance measures, air- and bone-conduction thresholds, and speech recognition thresholds) should be conducted to identify cases that are false positives and false negatives, something a screening measure cannot do.

Introduction

Prelingual and early childhood hearing loss can have an adverse affect on the developing auditory nervous system (Dornan, 2009) and may lead to delays in socio-emotional, cognitive, and academic development (American Speech-Language-Hearing Association [ASHA], 1997; Bess, Dodd-Murphy, & Parker, 1998; Downs, 1994; Gravel, Wallace, & Ruben, 1995; National Institutes of Health, 1993; Roberts, Burchinal, & Zeisel, 2002; Siegel, 2000). According to the National Center for Hearing Assessment and Management (NCHAM), every state and territory in the United States has now established an Early Hearing Detection and Intervention (EHDI) program (White, 2008). The goal of these EHDI programs is to identify every child born with a permanent hearing loss before three months of age. However, there are children who do not receive newborn hearing screenings because of other health issues and home/community birthing options. In addition, an estimated 20% of all cases of childhood hearing loss are progressive in nature or are acquired after the newborn hearing screening period (Georgalas, Xenellis, Davilis, Tzangaroulakis, & Ferekidis, 2008). Because of these pitfalls in the early screening process, hearing screenings at the pre-school and school-age level are important. These later screenings allow for identification of hearing loss that was not identified by newborn hearing screening programs because it is progressive, late-onset, or acquired by trauma, disease, or other environmental factors (e.g., noise exposure).

Current Hearing Screening Protocols

The Guidelines for Audiologic Screening published by ASHA (1997) outline the current methods for the screening of outer and middle ear disorders, as well as peripheral hearing loss in the school-age population. Otoscopy and tympanometry are the measures recommended by the ASHA Guidelines to screen for outer and middle ear disorders. According to ASHA, the primary goal of outer and middle ear screening is to identify children with chronic otitis media with effusion (OME), which has the potential to cause significant medical problems, hearing loss, and long-lasting speech, language, and learning deficits.

In addition to these two measures of screening for outer and middle ear pathologies, pure-tone hearing screenings are recommended for identifying peripheral hearing impairment (ASHA, 1997). The goal of screening pre-school and school-age populations for hearing loss is the identification of peripheral hearing impairments that may interfere with communication, development, health, or future academic performance (ASHA, 1997). In order to screen for middle ear disorders and hearing impairment, both tympanometry and pure-tone screenings must be used (Nozza, Sabo, & Mandel, 1997).

The goal of a good screening tool is to maximize the identification of individuals who need a referral for further diagnostic testing and to correctly identify individuals who do not need further testing. Sensitivity is defined as the likelihood that a test is able to detect the presence of a specific characteristic in someone who has that characteristic, and specificity is defined as the likelihood that a test is able to detect the absence of a specific characteristic in someone without that characteristic. Comparing one screening test to another screening test only examines the relationship between the two measures.

Otoacoustic Emissions as a Screening Tool

An alternative measure that has been used to screen for peripheral hearing loss, as well as outer and middle ear disorders, is otoacoustic emissions (OAEs; Driscoll, Kei, & McPherson, 2000, 2003; Eiserman, Shisler et al., 2008; Lyons, Kei, & Driscoll, 2004; Nozza et al., 1997; Sabo, Winston, & Macias, 2000; Yin, Bottrell, Clarke, Shacks, & Poulsen, 2009). OAEs are a physiological measure, highly reproducible, non-invasive, and well suited for use with infants, children, and other difficult-to-test populations. The presence of an OAE measured in an ear canal is considered evidence of the functional integrity of the entire middle ear and cochlear systems, including the basilar membrane, organ of Corti, stria vascularis, and outer hair cell system (Allen, 2001). OAEs are present in ears of children with normal peripheral auditory function and absent in children with middle ear pathology and/or hearing thresholds greater than 25 dB HL (Eiserman, Shisler et al., 2008; Georgalas et al., 2008; Nozza et al., 1997; Nozza, 2001).

OAE technology offers many benefits that make it ideal for conducting school-based hearing screenings (Driscoll et al., 2000; Eiserman, Shisler et al., 2008; Nozza, 2001; Yin et al., 2009). As a quick, objective, simple, and inexpensive tool, OAEs may be a good alternative to current screening tools. It takes approximately 2 minutes to complete an OAE screening, compared to 7 minutes (on average) for pure-tone screening (Foust, Eiserman & Shisler, 2011). OAEs do not require active participation, cooperation, or conditioning to the task, which are needed for pure-tone screenings. Personnel other than audiologists can be successfully trained to administer OAE screenings (Eiserman, Shisler et al., 2008; Nozza, 2001). Because OAEs can detect the presence of both middle ear disorders and peripheral hearing loss, the need for the school district to purchase and maintain multiple pieces of equipment (i.e., pure-tone audiometer and tympanometer) is potentially eliminated (Nozza et al., 1997). All of these characteristics of OAE screenings make them an attractive alternative to the current school-based hearing screening protocol. In fact, some authors have suggested that OAEs, coupled with otoscopy, could fulfill the current ASHA guidelines (1997) while possibly being more time efficient (Driscoll et al., 2000; Nozza et al., 1997; Nozza, 2001).

Transient evoked otoacoustic emissions (TEOAEs) and distortion product otoacoustic emissions (DPOAEs) are the two most commonly used evoked otoacoustic emissions in the clinical setting (Probst & Harris, 1993; Sabo et al., 2000). TEOAEs and DPOAEs differ mainly in the stimulus type used to evoke the emission. TEOAEs are elicited by a brief stimulus, such as a click or tone-burst, while DPOAEs are elicited by the simultaneous presentation of two pure tones. It has been suggested that DPOAEs offer more frequency-specific information than do TEOAEs, due to the nature of the stimuli (Gorga et al., 1993). Reportedly, DPOAEs are more sensitive to the higher-frequency region (i.e., 4000-6000 Hz) of the cochlea (Gorga, et al., 1993; Prieve, Gorga, Schmidt, Neely, Peters, Schultes, & Jesteadt, 1993).

Following the successful implementation of OAEs in newborn hearing screening, researchers began to examine the application for early childhood screenings. The Early Childhood Hearing Outcomes (ECHO) program has been successful in implementing such a protocol in Head Start and Early Head Start Centers (Eiserman, Behl, & Shisler, 2009; Eiserman, Hartel et al., 2008; Munoz, 2003). A child who fails (i.e., does not pass) the initial OAE screening is rescreened in two weeks. If a child fails the second screening, he is referred for medical clearance of middle ear problems and then sent to a pediatric audiologist for audiometric testing (Eiserman & Shisler, 2011). The ECHO program authors cite one of the main advantages of this model is the cost-efficiency and timeliness of follow-up. The ECHO model includes training Head Start staff to conduct screenings, which contributes to the cost efficiency of the protocol.

Rationale

Many studies have evaluated transient evoked otoacoustic emissions (TEOAEs) as a potential screening tool in pre-school and school-age populations (Driscol et al., 2000, 2003; Georgalas et al., 2008; Nozza et al., 1997; Sabo et al., 2000; Taylor & Brooks, 2000; Yin et al., 2009). Fewer studies have evaluated the use of distortion product otoacoustic emissions (DPOAEs) for hearing screenings in the school-age population (Lyons et al., 2004). Taylor and Brooks (2000) compared TEOAE screenings to pure-tone screenings for 297 ears of 152 children, aged 3 to 8 years. They calculated sensitivity as 81% and specificity as 95% when compared to pure-tone screenings and suggested that screening outcomes were comparable enough to consider substituting TEOAEs for traditional pure-tone screenings.

Lyons et al. (2004) examined DPOAE responses to determine optimal referral criteria compared to pure-tone screenings, tympanometric screenings, and a combined approach of pure-tone and tympanometric screenings. The authors reported that the use of DPOAE testing alone would have missed about 32 to 38% of children who failed a combined screening program of pure-tone screening plus tympanometry.

While pure-tone screenings remain the accepted procedure and best practice for school-based hearing screenings, further evaluation of DPOAE measurements for use as a screening tool is warranted. DPOAE measures are quick, inexpensive, and easy for screening personnel to learn and administer. In addition, DPOAEs are a noninvasive measure of the function of the ear from the ear canal to the outer hair cells of the cochlea. DPOAEs are well suited as a public health screening tool (Wilson & Junger, 1968). Therefore, the purpose of the current study was to compare the outcome of a DPOAE screening to the outcome of a pure-tone hearing screening for school-age children in kindergarten through second grade.

Methods

Participants

The sample consisted of 565 children (280 females, 285 males) who were enrolled in three different elementary schools in a suburban area in central Arkansas. There were 194 children in kindergarten, 181 in first grade, and 190 in second grade. These three grades are included in the routine hearing and vision screening program in the state of Arkansas. Children with known hearing loss do not participate in this hearing screening program; therefore, children with known hearing loss were not included in the sample.

Equipment

A DSP Pure-Tone Audiometer® and TDH-39 headphones (Micro Audiometrics Corporation) were used for the pure-tone screenings and were calibrated to the American National Standards Institute (ANSI) S3.6-1989 standards (1989). An AuDX OAE testing device manufactured by Bio-logic was used for the DPOAE screenings (Bio-logic Systems Corporation). Probe tips supplied by the manufacturer were used with this equipment.

Procedures

All participants underwent a pure-tone screening and a DPOAE screening. The order of the two screening measures was counterbalanced. In accordance with ASHA guidelines, the pure-tone screenings were conducted at 1000, 2000, and 4000 Hz with a passing criterion of 20 dB HL in both ears (ASHA, 1997). Participants were instructed to raise a hand to indicate when the tone was heard. Failure to respond to one or more frequencies in either ear resulted in a "refer" on the pure-tone screening.

For the DPOAE screenings, an appropriately-sized probe tip was selected and placed in the ear canal of each ear. The manufacturer's default protocol was utilized for the screenings. The 2f1-f2 distortion product was evaluated at stimulus intensities of 65 (f1) and 55 (f2) dB SPL for the following f2 frequencies: 2000, 3000, 4000, and 5000 Hz. The f2/f1 ratio was set at 1.22. The time window was set at a maximum of 10 seconds per test frequency. At each frequency, the DP response amplitude had to meet a minimum level of at least 6 dB SPL above the noise floor for inclusion in the average. If three of the four test frequencies met the manufacturer's criterion, a "pass" result was obtained for that ear (Bio-logic Systems Corporation, 2002).

Results

A total of 565 participants were tested; however, 18 individuals had to be excluded because data on one or both ears could not be obtained (e.g., a child refused the second screening measure, a child exhibited drainage in an ear, or a child refused screening in the second ear). Therefore, data were analyzed on a total of 547 participants. Because an individual is referred for a full diagnostic evaluation upon failing just one frequency in either ear, results were reported for each individual participant, not each ear.

There were 369 (67%) individuals who passed both the pure-tone and DPOAE screenings, while 38 (7%) individuals failed ("referred on") both screenings. Additionally, there were 61 (11%) individuals who passed the pure-tone screening but failed the DPOAE screening, and 79 (14%) individuals who passed the DPOAE screening but failed the pure-tone screening. A McNemar test was used to analyze the proportion of individuals who had different results on each screening measure (e.g. the 61 and 79 participants). The McNemar Chi-square test indicated there was not a statistically significant difference in the proportion of individuals who passed the pure-tone screening but failed the DPOAE screening and those who passed DPOAE screening but failed the pure-tone screening [$\chi^2(1, N=547) = 2.06, p=.151$)]. The crosstabulation results are presented in Figure 1.

		Pure-Tone		
		Pass	Refer	Total
DPOAE	Pass	369 (67%)	79 (14%)	448 (82%)
	Refer	61 (11%)	38 (7%)	99 (18%)
	Total	430 (79%)	117 (21%)	547 (100%)

Figure 1. Two by two (2x2) contingency table depicts pass/refer results for pure-tone and distortion product otoacoustic emission screening.

Four hundred and seven (74%) participants had the same outcome on both screening measures, either pass (*n*=369) or fail/refer (*n*=38). However, 140 (26%) of the participants were classified as "pass" or "refer" by one of the screening measures, but not both. Of the 79 participants (14%) classified as "pass" by OAEs but "refer" by pure tones, 14 were referred due to the right ear, 26 were referred due to the left ear, and 39 were referred for both ears. Of the 61participants (11%) classified as "pass" by pure tones but "refer" by OAEs, 16 were referred due to the right ear, 17 were referred due to the left ear, and 28 were referred for both ears.

Discussion

The purpose of the current study was to compare the outcome of a DPOAE screening to the outcome of a pure-tone screening for school-age children in kindergarten through second grade. Seventy-four percent of these children obtained the same results on both screening measures; however, 26% had differing results. Therefore, it was unclear whether the children with differing results had hearing sensitivity that was of concern, or whether one or both of the results of the screening measures resulted in over or under identification. Without a follow-up diagnostic test, in a clinical rather than educational setting, the exact relationship between the two screening tests cannot be determined. Likewise, sensitivity and specificity for screening methods used in this study could not be calculated for this data due to the lack of diagnostic data. A diagnostic evaluation would identify the cases that were false positives and false negatives, something a screening test cannot do. Furthermore, because there were no known clinical cases included in this study, positive predictive power and negative predicative power could not be calculated.

A number of factors may have contributed to the referral of children who passed the pure-tone screening but referred on the DPOAE screening (N=61). Although ambient noise levels may have been acceptable for the pure-tone screenings, those same noise levels could have been loud enough to interfere with the measurement of the OAE (Frank, 2000). Cerumen in the ear canal may have blocked or entered the probe tip, causing increased referrals. Middle ear disease (e.g., fluid in the middle ear) may have affected the outcome of the DPOAE screening, but not the pure-tone screening if the middle ear disorder was not significant enough to impact hearing thresholds.

Pure-tone screening is a behavioral test and subject to human test error. For example, a potential error that may occur includes inadvertently giving the child visual cues. Children who passed the DPOAE screenings but were referred on the pure-tone screenings (N=79) may not have been able to perform the pure-tone screening task. Children considered difficult-to-test or children who did not understand the directions for the pure-tone screenings would have been unable to perform the task required of them for the pure-tone screening. In addition, children with auditory neuropathy may have failed the pure-tone screenings but passed the OAE screenings.

DPOAEs are not considered to be a test of hearing sensitivity, but an assessment of cochlear outer hair cell function. When conducting a DPOAE screening, the function of the cochlear inner hair cells and auditory nerve is unknown. If an OAE screening were the only assessment tool implemented, a child having normal outer hair cell function and abnormal function further up the auditory pathway, as seen in cases of auditory neuropathy, may be missed or incorrectly identified as not having a hearing loss (Rapin & Gravel, 2003; Starr, Picton, Sininger, Hood, & Berlin, 1996).

The purpose of a screening test is to quickly and accurately separate individuals who may have a hearing loss from those who do not. Researchers have shown DPOAE stimulus levels of 65/55 dB SPL to be the most accurate intensity levels for use in categorizing individuals into one of two categories with 20 dB HL used as the criterion (Stover, Gorga, Neely & Montoya, 1996). Depending upon the stimulus level, DPOAEs may be elicited in individuals with mild hearing loss (Gorga et al., 1993; Harrison & Norton, 1999; Probst & Harris, 1993). The use of DPOAE screening equipment with preset parameters helps reduce human test error.

Automated technology is expanding at a rapid rate and researchers continue to seek information that will contribute to better DPOAE test performance. Improved algorithms for DPOAE screening may lead to improved screening outcomes. Algorithms for DPOAE screening equipment are proprietary; therefore, care must be taken when selecting screening equipment. Equipment purchased from manufacturers who provide disclosure of screening stimuli parameters is desirable.

A screening test with 100% accuracy does not exist. However, by continuing to compare screening tools and by reporting sensitivity and specificity without follow up diagnostic testing, the possibility of over-referrals (or worse, under-referrals) remains, and the knowledge base of the profession of audiology will not improve.

Conclusion

A well-defined and universally accepted pass/refer DPOAE criteria for the school-age population has yet to be established. In future studies, comparing pure-tone and DPOAE screening results with a full diagnostic evaluation, including otoscopy and tympanometry, should be performed. The feasibility of a screening protocol is dependent upon it meeting the requirements of public health screening criteria (Wilson & Junger, 1968), as defined by the World Health Organization (WHO). The data in the present study adds to the body of literature indicating that OAEs may not be a direct substitute for pure-tone screenings. In light of the limitations to using a DPOAE screening for identifying hearing impairment, additional research is needed. Advances in digital signal processing algorithms may contribute to improved DPOAE test performance. Therefore, more research is needed to evaluate the cost- and time-effectiveness of DPOAE screening protocols for the school-age population and the continued evaluation of a school hearing screening protocol utilizing DPOAEs is warranted.

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Spatial Hearing in Noise of Young Children with Cochlear Implants and Hearing Aids

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The primary goals of this investigation were (1) to determine the sensitivity of the Phrases in Noise Test (PINT) for identifying children with hearing loss who were at risk for educational difficulties in the classroom, (2) to examine the effects of spatial location of the speech and noise sources on the speech recognition in noise of participants using bilateral cochlear implants (CIs), bilateral hearing aids, or a CI on one ear and hearing aid on the non-implant ear (bimodal stimulation), and (3) to determine the relationship between teacher ratings of educational risk and speech recognition in noise. Twenty-nine children using bilateral CIs, bilateral hearing aids, or bimodal stimulation were tested with the PINT in conditions with speech and noise from the same location or from separate locations in a small room. Teachers of the participants were asked to complete the Preschool Screening Instrument for Targeting Educational Risk (S.I.F.T.E.R.). Average results from the three groups of children suggest significant spatial release from masking, where the spatial separation of speech and noise sources resulted in improved speech-in-noise thresholds. Several medium and strong negative correlations were calculated, where poorer speech-in-noise thresholds on the PINT were related significantly to at-risk Preschool S.I.F.T.E.R. ratings from teachers. In comparison to PINT performance in age-matched children with normal-hearing sensitivity from a previous study, 93% of children in the present study have significantly poorer PINT thresholds. A combination of the PINT and the Preschool S.I.F.T.E.R. may be used by educational audiologists to identify young children with hearing loss who have educational need for classroom accommodations and hearing assistance technology.

Introduction

Factors Influencing Children's Speech Recognition

In a typical classroom environment, students with hearing aids and cochlear implants (CIs) experience considerable difficulty hearing and comprehending teachers and classmates because of the room acoustics, competing background noise, effects of age, and presence of hearing loss. Typical classrooms do not provide ideal listening or learning situations for any child due to the excessive unoccupied and occupied noise levels, long reverberation times, and poor signal-to-noise ratios (SNR; Arnold & Canning, 1999; Knecht, Nelson, & Whitelaw, 2002; Sanders, 1965). In fact, previous research suggested that few classrooms met the current recommendations of the American Speech-Language-Hearing Association (ASHA) for unoccupied noise levels and reverberation times (ASHA, 2005; Knecht et al., 2002). When occupied, classrooms with poor acoustics are likely to pose an even greater hearing challenge due to the fluctuating background noise levels throughout the day. The background noise level in a classroom fluctuates because of various classroom activities (lecture, group work), use of classroom equipment (computers, projectors, cycling ventilation systems), sources outside the classroom (hallways, other classrooms), and teacher movement around the room during instruction.

Younger children (≤ 5 to 6 years) are at an even greater disadvantage than older children and adults in classrooms with poor acoustics because there is a developmental effect associated with speech recognition performance in the presence of background noise (Papso & Blood, 1989; Litovsky, 2005; Jamieson, Kranic, & Yu, 2004; Johnstone & Litovsky, 2006; Neuman, Wroblewsi, Hajicek, & Rubinstein, 2010; Schafer et al.,in press). For example, Jamieson and colleagues (2004) reported that 5- to 6-year-old children with normal-hearing sensitivity (Mean 74-76%) had significantly poorer speech recognition in classroom noise at a -6 SNR than 7- to 8-year-old children (Mean 97-95%). These age-related differences may be attributed to numerous factors, some of which include maturation, cognition, language comprehension, and working memory (Montgomery, 2008; Magimairaj & Montgomery, 2012; Montgomery, Magimairaj, & O'Malley, 2008).

The age of the child may also influence speech recognition in noise when the speech and noise are presented from different spatial locations. In a recent study in our laboratory (Schafer et al., in press), we reported significantly poorer speech recognition performance in four-classroom noise for a group of 3-year olds with normal-hearing sensitivity as compared to groups of 4-, 5-, and 6-year olds. In addition, 3-, 4-, and 5-year olds had significantly poorer speech recognition in noise than adults. In this study, the largest age differences occurred in a condition with speech and noise presented from the same spatial location (S0/N0) as compared to a condition with spatially-separated speech and noise sources (S0/N180), which is often referred to as a spatial release from masking (SRM). Therefore, the difficulty of a speech-recognition-in-noise task may be related to the location of the speech and noise stimuli, with spatially coincident stimuli (S0/N0) resulting in the most challenging listening situation.

The investigators' definition of SRM is the difference in dB between conditions with speech and noise from the same loudspeaker (S0/N0) versus speech and noise from different loudspeakers (most typically S0/N90). SRM is influenced by all factors contributing to speech recognition in noise, some of which include the child's speech reception threshold in quiet, background noise level at threshold, developmental level, auditory working memory, language comprehension, auditory attention, and binaural auditory processing ability. Therefore, the measurements of a child's thresholds in noise as well as SRM provide audiologists a tool that may be used to assess a broad range of functional capabilities in the auditory domain. Furthermore, measuring SRM in children with hearing loss is critical because it supports the need for (1) preferential seating near the teacher in typical classrooms, (2) directional microphone technologies in hearing aids and CIs, and (3) hearing assistance technology (HAT), such as frequency modulation (FM) systems.

According to previous investigations, the presence of SRM, as measured in S0/N0 and S0/N90 conditions, in children with hearing aids and CIs is variable. For example, in one study that included children with bilateral CIs and bimodal stimulation, significant SRM of 5.2 dB was found when noise was shifted from the front (S0/N0) to the side of the second CI or hearing aid (S0/N90), but an SRM of only 1.8 dB was reported when noise was shifted from the front to the side of the first or only CI (Litovsky, Johnstone, & Godar, 2006). However, in another study including children with bilateral CIs and similar test conditions, children achieved significant SRM with noise shifts to both sides (Van Deun, van Wieringen, & Wouters, 2010). Similar to the Litovsky et al. (2006) study, a comparison of SRM between the conditions with noise presented to the first CI (1.6 dB) versus noise presented to the second CI (-4 dB) yielded significant larger SRM with noise to the second CI (Van Deun et al., 2010). Finally, in a study on children with hearing aids, the authors reported no significant SRM for word (0.63 dB) or sentence stimuli (0.17 dB) presented in a S0/N0 condition versus a condition with simultaneous noise from two loudspeakers at + 90 degrees azimuth (Ching, Wanrooy, Dillon, & Carter, 2011). Given the variability across these three studies, and the importance of SRM for children with hearing loss, additional research on SRM in children with hearing aids and CIs is warranted.

Adding to the challenges from the combined effects of typical classroom acoustics and age is the presence of sensorineural hearing loss. For example, an early comparison study between children with normal-hearing sensitivity and children with hearing loss suggested significantly poorer speech recognition for the children with hearing loss by up to 85% in conditions with increasing noise and reverberation times relative to peers in an ideal listening situation (Finitzo-Hieber & Tillman, 1987). In CIs, advances in front-end processing, sound processing strategies, directional microphones, and use of bilateral CIs and bimodal stimulation as compared to a unilateral CI have significantly improved speech recognition of children and adults with CIs (Ching, 2000; Schafer, Amlani, Seibold, & Shattuck, 2007; Schafer, Amlani, Paiva, Nozari, & Verrett, 2011; Wolfe, Schafer, John, & Hudson, 2011; Wolfe et al., 2012), but these users continue to experience significantly decreased speech recognition performance in the presence of background noise and reverberation as compared to conditions in quiet or to normal-hearing peers (Schafer & Thibodeau, 2004; Stickney, Assman, Chang, & Zeng, 2007). Specifically, when compared to quiet listening conditions, speech recognition of children and adults with CIs decreased by up to 45% in the presence of background noise (Firszt et al., 2004; Schafer & Thibodeau, 2003, 2004). Users of hearing aids have also experienced significant benefit from improved technology, such as frequency compression and directional microphones (Auriemmo et al., 2009; Wolfe et al., 2011), but similar to users of CIs, children and adults with hearing aids show significant decreases in speech recognition in noise on the order of 40% relative to a quiet condition (Auriemmo et al., 2009) or to peers with normal-hearing sensitivity (Scollie, 2008). Reasons for the poorer performance in noise of children with CIs and HAs is likely related to numerous factors, but most importantly, CIs and hearing aids cannot completely separate the primary speech signal from the competing background noise (i.e., poor SNRs), and these devices cannot restore normal auditory function.

Importance of Assessing Speech Recognition

Determining the combined effects of classroom acoustics, competing background noise, age, and hearing loss on a child's speech recognition performance is critical for educational audiologists who will need to identify and quantify educational need. Educational need as it relates to hearing loss, which the authors define as significantly poorer performance in one or more area of assessment (e.g., speech recognition, communication, listening behavior, etc.) than normal-hearing peers, is often a prerequisite to special education services or purchase of HAT, especially for children who are functioning on grade level and are educated in general education classrooms. Furthermore, speech recognition testing may be used to document benefit of HAT, over a CI or a hearing aid alone, after it is fit on a child (American Academy of Audiology, 2008). Therefore, assessments of speech recognition performance in noise and educational need are important for all school-aged students with hearing loss, which also includes preschool-aged children from 3 to 6 years.

At this time, there are few sensitive speech perception measures specifically designed for testing in noise that are also appropriate for young children (see Schafer, 2010 for a review). The few tests that are commercially available are not designed for use in noise, contain higher-level vocabulary, or may result in ceiling and floor effects (0% or 100%) from percent-correct scoring. For example, commonly used pediatric tests, such as the Word Intelligibility by Picture Identification (WIPI; Cienkowski, Ross, & Lerman, 2009; Ross & Lerman, 1970; Ross, Lerman, & Cienkowski, 2004) and the Northwestern University-Children's Perception of Speech Test (NU-CHIPS; Elliott & Katz, 1980), do not have equivalent word lists in the presence of background noise (Chermak, Pederson, & Bendel, 1984; Chermak, Wagner, & Bendel, 1988). The pediatric speech recognition tests that are designed for use in noise, such as the Hearing in Noise Test for Children (HINT-C; Nilsson, Soli, & Sullivan, 1994) or the Bamford-Kowal-Bench Speech-in-Noise test (BKB-SIN; Etymotic Research, 2005) have vocabulary levels that exceed that of a typical 5-year old child. Finally, the one test that is designed for young children and for use in noise, the Pediatric Speech Intelligibility test (PSI; Jerger & Jerger, 1982, 1984), may result in ceiling and floor effects or the need to administer multiple lists to find the most appropriate SNR for each child in order to avoid these effects. Unfortunately, young children may not have the attention spans necessary to complete multiple PSI speech recognition lists at different SNRs. Also, the single-talker competitor used for this test may not replicate the type of multi-source noise encountered in typical classrooms.

Rationale for Investigation

Given the need for a sensitive speech recognition test in noise for young children, the goals of this study are (1) to determine the sensitivity of a newly-developed measure, the Phrases in Noise Test (PINT), for identifying children with CIs and/or hearing aids who are at risk for educational difficulties in the classroom; (2) to examine the effects of spatial location of the speech and noise sources (SRM) on the speech recognition in noise of the participants using bilateral CIs, bilateral hearing aids, or a CI on one ear and hearing aid on the non-implant ear (bimodal stimulation); (3) to examine and to compare the relationship between teacher ratings of educational risk to the children's speech recognition in noise.

The PINT estimates a child's speech-in-noise threshold at the 50% correct level and requires the child to act out the speech stimuli with a stuffed animal or doll. The PINT stimuli include 12 simple phrases (Table 2) and four-classroom noise that ascends and descends in intensity. This test paradigm is similar to the one used by the creators of the BKB-SIN test (Etymotic Research, 2005), where a range of SNRs are pre-recorded on a compact disc (CD). The PINT task has slightly higher auditory complexity than simple word identification because it requires the child to detect the phrase (or word), recognize the phrase, and carry out the associated action (i.e., follow instructions). Also, because this test requires an action from the child instead of a verbal response, the presence of articulation problems, which may influence the child's speech intelligibility to an examiner, does not influence the reliability of examiner scoring.

Although the PINT has been used in previous investigations to assess speech-in-noise thresholds in young children with normal-hearing sensitivity or CIs (Schafer & Thibodeau, 2006; Schafer et al., in press), the sensitivity of the test for identifying children who have educational need for services in the schools has yet to be determined. Individual results of the children in the present study may be compared to PINT data from children with normal-hearing sensitivity in a previous investigation (Schafer et al., in press) to determine a child's level of performance relative to peers. In addition, unlike previous investigations of SRM in children with hearing loss (e.g., Ching et al., 2011; Litovsky et al., 2006; Van Deun et al., 2010), the listening conditions included in this study will (1) investigate the presence of SRM in three different populations of young children using binaural listening arrangements, (2) use the same speech recognition measure (PINT) with each population, and (3) utilize a different noise loudspeaker location for conditions with spatially-separated speech and noise sources (S0/N180 used instead of the S0/N90 configuration used in previous investigations). Overall, the children with hearing loss are expected to perform worse than children with normal-hearing sensitivity in a previous investigation (Schafer et al., in press), which will support the sensitivity of the PINT for the detecting speech recognition difficulty in background noise as compared to peers. Additionally, performance on the PINT will be compared to teacher ratings on a screening tool to examine children's levels of educational risk as compared to peers. The examiners hypothesize that strong correlations will be calculated between the teacher ratings on the screening instrument and speech recognition in noise performance on the PINT.

Methods

Participants

A total of 29 children, ages 2;8 to 7;3 years, were included in this investigation. The children were using bilateral CIs (n=13), bilateral hearing aids (n=10), or bimodal stimulation (n=6). In order to participate, children had to act out all 12 PINT phrases in a quiet condition with 100% accuracy after familiarization. Children that could not complete this task were dismissed from the study. All children had spoken English as a first language, had no history of recurrent otitis media (defined as more than six occurrences), and had no cognitive issues via parent report on a case history form. All children were receiving special education services or other private speech-language therapy. With the exception of three children using bilateral hearing aids (Subjects 21-23) and one child using bimodal stimulation (Subject 25), participants were enrolled in Auditory-Verbal Therapy with a certified Listening and Spoken Language Specialist (LSLS). Children were enrolled in one of the following educational placements: private oral school for students with hearing impairment (n=8), public preschool or elementary school (n=10), mainstreamed private school (n=8), home school (n=2), and Head Start program (n=1). Specific information about the ages, devices, and duration of device use for the participants is provided in Table 1. The average unaided audiogram for the bilateral hearing aid group is provided in Figure 1. The investigators were unable to obtain unaided audiograms for the non-implant ear of all the children in the bimodal group, but audiograms of three participants reveal a moderately-severe-to-severe (Subject 25), severe-to-profound (Subject 26), and mild-to-severe (Subject 27) sensorineural hearing loss in the non-implant ear. (See Table 1 page 10)

The examiners aimed to replicate the most likely listening condition used during a school day; therefore, during testing, children were using their normal, everyday settings on their hearing aids and CIs. The parents reported that these settings were used at school. The hearing aids worn by the children may have utilized adaptive noise reduction programs and directional microphones; however, some audiologist may have deactivated these features. Use of directional microphones in an environment with spatial separation of speech and noise sources could significantly improve a child's speech recognition in noise by 3 to 7 dB relative to their performance or other children's performance without directional microphones in the same condition (Amlani, 2001; Auriemmo et al., 2009). To our knowledge, there is no strong evidence to support noise reduction strategies in children. However, there is some evidence that use of noise reduction improves listening comfort and the acceptable noise levels of adults with hearing aids (Mueller & Bentler, 2005).

Several of the children in the bilateral hearing aid group (n=6) and bimodal group (n=5) utilized hearing aids with frequency compression (i.e., Phonak Naida and Nios shown in Table 1). After a period of at least six months of use, instruments with frequency compression may have provided the subjects with bilateral hearing aids significantly improved speech recognition in quiet and in noise due to the improved audibility of high-frequency speech sounds (Glista, Scollie, & Sulkers, in press; Wolfe et al., 2011). There is limited evidence regarding the benefit of frequency compression for users of the bimodal arrangement. Although, one study suggested that, while the bimodal arrangement was beneficial relative to the CI alone, use of the frequency compression algorithm did not result in better performance than a hearing aid with no frequency compression (Park, Teagle, Buss, Roush, & Buchman, in press). Prior to speech recognition testing, all hearing aids used by participants were tested in a hearing aid test box (AudioScan Verifit) using the American National Standards Institute standard criteria (ANSI S.3.22-2003) to verify functioning. In hearing aids employing frequency compression, the frequency compression (i.e., limited high-frequency gain) was always visible to the examiner in the ANSI test and was used by all participants with Phonak Nios or Naida hearing aids (Table 1).

Regarding signal processing for the children with CIs, the investigators believe that it is highly unlikely that any of the children with CIs were using a noise program as his or her most common

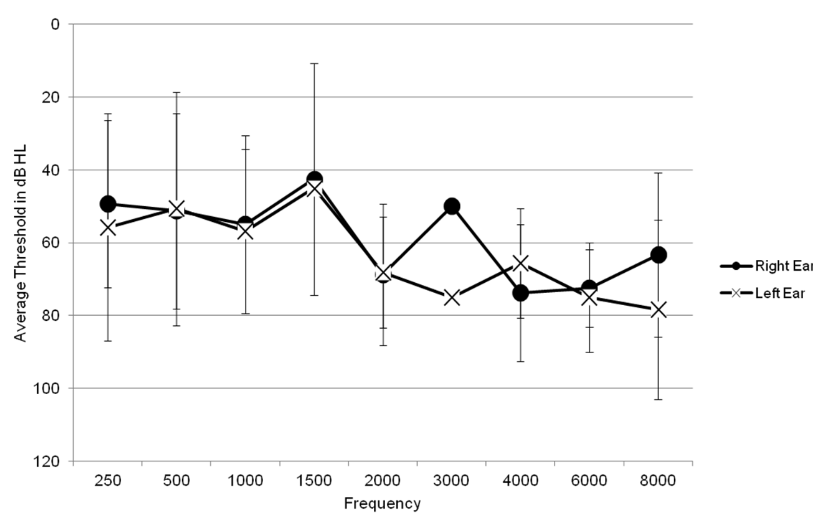

Figure 1. Unaided thresholds of the participants in the bilateral hearing aid group.

Table 1. Participant Information

	Subject	Age	CI Sound Processor(s)	HA Make/Model	Duration 1st CI	Duration 1st HA	Duration Binaural Use
Bilateral Cochlear Implant Group	1	6;5	Freedom	.	3;2	0;2	4;3
	2	6;11	Freedom	.	5;8	0;7	5;9
	3	6;8	Nucleus 5	.	5;2	5;0	0;2
	4	6;11	OPUS 2	.	5;4	.	5;2
	5	4;5	OPUS 2	.	3;3	0;7	3;5
	6	4;0	OPUS 2	.	2;3	0;3	2;4
	7	2;10	Nucleus 5	.	1;10	1;1	1;6
	8	6;4	OPUS 2	.	1;0	5;6	1;0
	9	4;5	Harmony	.	3;7	0;3	3;7
	10	4;1	Freedom	.	2;0	1;0	2;0
	11	4;7	Freedom	.	3;0	0;3	3;1
	12	4;10	Freedom	.	2;8	2;0	2;10
	13	4;0	Freedom	.	2;6	0;2	2;6
	Average	**5;0**	.	.	**3;2**	**1;4**	**3;3**
Bilateral Hearing Aid Group	14	6;2	.	Phonak Maxx 311 Forte	.	3;7	3;7
	15	3;11	.	Phonak Naida	.	0;11	0;11
	16	6;7	.	Phonak Naida	.	4;9	4;9
	17	6;4	.	Oticon Sumo DM	.	4;0	4;0
	18	4;4	.	Phonak Naida III SP BTE	.	3;7	3;7
	19	6;6	.	Phonak Naida V SP Junior	.	2;0	2;0
	20	6;0	.	Phonak Nios micro	.	4;0	4;0
	21	7;3	.	Phonak Nios micro	.	1;11	1;11
	22	3;10	.	Phonak Nios micro	.	1;11	1;11
	23	6;1	.	Starkey Destiny 1200	.	.	.
	Average	**5;6**	.	.	.	**2;11**	**2;11**
Bimodal Stimulation Group	24	4;10	OPUS 2	Phonak Nios III	1;3	2;0	1;3
	25	6;8	Freedom	Phonak Maxx 311 Forte	1;7	3;8	1;7
	26	4;6	Nucleus 5	Phonak Naida III SP	1;6	4;3	1;6
	27	3;4	OPUS 2	Phonak Naida III SP	1;0	2;1	1;0
	28	3;8	OPUS 2	Phonak Naida	1;11	3;2	1;11
	29	3;3	OPUS 2	Phonak Naida	2;1	3;1	2;1
	Average	**4;4**	.	.	**1;7**	**3;0**	**1;7**

Note. CI=cochlear implant; Ages and durations of use are in years and months; dot represents not applicable or unknown.

setting. However, if a child was using a noise program, such as the noise program in Cochlear processors containing Autosensitivity (ASC) and Adaptive Dynamic Range Optimization (ADRO), their performance in noise would be enhanced relative to performance with their everyday program (Wolfe et al., 2011). Specific fitting algorithms or methods to program the CIs were not available to the investigators because the children were fit at various centers and clinics. Functioning of each separate CI worn by a child was verified through a behavioral listening check, which consisted of the examiner asking the child to repeat words or sounds with no visual cues.

The reader should note that the exact settings used by the children with hearing aids and CIs were unknown to the examiners, and the potential impact of these technologies were not within the scope of the present investigation. Therefore, the reader should exercise caution when attempting to relate any of the findings in this study directly to one or more technologies that were or were not enabled in the children's hearing aids or CIs.

Test Rooms and Equipment

Testing was conducted in several small rooms where the children were seen for audiological services and/or speech-language therapy. Real rooms, rather than sound booths, were used to ensure that results represented speech recognition performance in an environment with acoustics that are more commonly encountered by children with hearing loss. Testing was conducted in a total of six different rooms. Within each group, bilateral CI participants were tested in a total of five different rooms, bilateral hearing aid participants were tested in two rooms, and bimodal stimulation participants were tested in four rooms. In each room, participants were seated at a small table in the middle of the room. Although testing in a single room would have been preferable to the investigators, the sample sizes in each group would have been severely limited. The examiners had to travel up to four hours to test some of these participants.

The use of multiple rooms for testing was not expected to influence the results of the study because the acoustics varied only slightly across the rooms. Specifically, with the exception of one room where only one bimodal participant was tested, all rooms met the ANSI (2010) and ASHA (2005) recommendations for unoccupied noise levels (< 35 dBA) and reverberation times (< 0.6s) in classrooms. The single room that did not meet the ASHA and ANSI recommendations had an average unoccupied noise level of 42.0 dBA across eight measurements around the room. This higher noise level was not expected to negatively influence performance because the PINT is conducted in the presence of background noise, and the calibration procedure for the PINT accounts for unoccupied noise levels. This same room also had the longest reverberation time of any room in the study (0.4 s); however, this room met the ASHA recommendation for classroom reverberation. In addition, previous research suggests that an increasing reverberation time from 0.3 to 0.6 seconds only results in a change in speech recognition performance by an average of 1 dB (SD approximately .5 dB) in six-year-old children (Neuman, Wroblewski, Hajicek, & Rubinstein, 2010). Therefore, given the 3-dB step size of the PINT stimuli, and the narrow range of reverberation times measured for the rooms in this study (0.3 to 0.4 seconds), differing reverberation times would not be expected to contribute to any variation in the thresholds-in-noise across participants within each group.

The speech and noise stimuli were presented via CD with a Sony CD-Radio-Cassette-Corder (Sony CFD-ZW755), two detachable, single-coned loudspeakers, and additional speaker wire. The loudspeakers were 3 feet from the listener at head level and were placed at 0 and 180 degrees azimuth relative to the listener. Stimuli intensities were calibrated using a calibration track on the CD and a sound level meter (Larson-Davis 824).

Speech Recognition Test Stimuli

According to previous investigations, the PINT (Schafer et al., in press; Schafer & Thibodeau, 2006) is a sensitive, valid, and reliable tool for estimating a child's speech in-noise threshold at the 50% correct level. The current version of the PINT consists of 12 simple, equally-intelligible phrases, spoken by a female speaker, in the presence of four-classroom noise that ascends and descends in intensity during testing (Schafer et al., in press). The Flesch-Kincaid Grade Level of the PINT stimuli was measured as 0.0 (Kincaid, Fishburne, Rogers, and Chissom, 1975), which suggests the lowest vocabulary level measurable on this test. In addition, the appropriateness of the stimuli was verified in three previous studies involving young children who successfully completed the PINT in quiet and in noise (Schafer, 2005; Schafer et al., in press; Schafer & Thibodeau, 2006).

The PINT is similar to the BKB-SIN Test (Etymotic Research, 2005) where a range of SNRs are pre-recorded on a CD. However, unlike the BKB-SIN, children are familiarized with the phrases prior to testing. Also, during testing, children are asked to act out the phrases with a doll and several associated objects in order to avoid examiner scoring issues associated with the child's speech intelligibility (potential articulation errors).

There were a total of 12 PINT lists included on the CD. Each list consisted of 24 pseudo-randomized phrases with each of the 12 phrases occurring twice. As shown in Figure 2, a PINT list consists of phrases presented at approximately 60 dBA (actual intensity of each phrase resulted in equal intelligibility for the normal-hearing adult participants) in the presence of four-classroom noise that decreases by 3 dB for 12 consecutive steps and increases by 3 dB for 12 consecutive steps. The wide range of SNRs was chosen to facilitate testing in children with varying degrees of hearing loss and for testing with FM systems where many children are able to achieve 50% correct performance on the PINT at negative SNRs (Schafer, 2010; Schafer & Thibodeau, 2006).

Phrases in Noise Test (PINT)
LIST ONE - SPEECH 0° / NOISE 180°

Condition:

Trial	SNR	Phrase	Response	Trial	SNR	Phrase	Response
1.	+15	Blow his nose	+	13.	-18	Stomp his feet	–
2.	+12	Brush his teeth	+	14.	-15	Blow his nose	–
3.	+9	Touch his tongue	+	15.	-12	Hide his face	–
4.	+6	Pull his toes	+	16.	-9	Pat his leg	–
5.	+3	Find his shoe	+	17.	-6	Find his shoe	–
6.	0	Hide his face	–	18.	-3	Move his arm	+
7.	-3	Hold his hand	–	19.	0	Touch his tongue	–
8.	-6	Move his arm	–	20.	+3	Pull his toes	–
9.	-9	Pat his leg	–	21.	+6	Wipe his mouth	+
10.	-12	Wipe his mouth	–	22.	+9	Hold his hand	+
11.	-15	Stomp his feet	–	23.	+12	Brush his teeth	+
12.	-18	Comb his hair	–	24.	+15	Comb his hair	+

Average = + 3

Figure 2. Sample PINT scoring form.

The 12 PINT lists on the CD included six, single-channel tracks for conditions with speech and noise from the same loudspeaker located directly in front of the child (S0/N0) as well as six, two-channel tracks for conditions with speech and noise from separate loudspeakers located at 0 and 180 degrees azimuth (S0/N180), respectively. The S0/N180 condition represents a testing arrangement that may be used by educational audiologists in real classrooms, simulates preferential seating in a small classroom, and may be used for aided testing with unilateral or bilateral hearing aids, CIs, and FM systems. The S0/N180 condition is also preferred because the more common S0/N90 condition would require two conditions with spatial separation with noise speakers toward the right and left sides of the listener. A practice PINT list in quiet and a calibration track were also included on the CD, which consisted of white noise filtered to match the long-term-average spectrum and average root-mean-square intensity of the phrases. Scoring for the PINT was determined in previous investigations (Schafer et al., in press; Schafer & Thibodeau, 2006). To summarize the scoring, on the left-side of the scoring form (Figure 2), the examiner circles the last correct response that is followed by two consecutive incorrect responses, and on the right side, the examiner circles the first correct response that is followed by two consecutive correct responses. The two SNRs associated with the circled responses are averaged to obtain the estimated threshold in noise in dB SNR on a list.

Teacher Questionnaire

The Preschool Screening Instrument for Targeting Educational Risk (Preschool S.I.F.T.E.R.; Anderson & Matkin, 1996) was completed by some of the children's primary teachers to identify any children who were at-risk for potential educational difficulties and to compare these levels of risk to the children's speech recognition in noise performance. The Preschool S.I.F.T.E.R. consists of primary ratings for expressive communication and socially-appropriate behavior as well as five content areas including pre-academics, attention, communication, class participation, and social behavior. Scale scores for the two primary areas and the five content areas were examined for each child.

Procedure

Once informed consent was obtained from the child's parent, the examiner read each phrase aloud while simultaneously showing the participant how to act the phrase with a stuffed animal and several objects (Table 2). After familiarization, the child was required to get 100% correct accuracy using the CD practice list in quiet to continue with the test protocol. Each participant completed four randomized test conditions: two S0/N0 PINT lists and two S0/N180 PINT lists. To receive a correct response, the child had to act out the entire phrase. During testing, the parent was asked to complete a case history form. Parents were asked to take a Preschool S.I.F.T.E.R., instructions, and an envelope with pre-paid postage to the child's primary teacher if the child was enrolled in a preschool or elementary school.

Results

Speech Recognition in Noise Performance

Average speech-in-noise thresholds of the children with bilateral CIs, bilateral hearing aids, and bimodal stimulation in the S0/N0 and S0/N180 testing conditions are shown in Figure 3 along with data from children with normal hearing in the Schafer et al. (in press) study, which will be further examined in the discussion section. Within-group comparisons using a one-way repeated measures analysis of variance (ANOVA) revealed significant benefit from spatial separation of the speech and noise sources for the group with bilateral CIs ($F\,[1,25] = 8.0$, $p = .02$), bilateral hearing aids ($F\,[1,19] = 10.4$, $p = .01$), and bimodal stimulation ($F\,[1,11] = 19.4$, $p = .007$). These results suggest that all three groups achieved significant SRM on the order of 3.4 dB (SD=4.3) for the bilateral CI group, 5.3 dB (SD=5.2) for the bilateral hearing aid group, and 4.6 dB (SD=2.6) for the bimodal stimulation group. Statistical comparisons among the groups were not appropriate because of the relatively small and unequal sample sizes and because the groups were not purposefully matched for chronological age, listening age, or any other specific characteristics (e.g., hearing thresholds, duration of use, etc.).

Table 2. PINT Phrases and Related Objects Used During Test Conditions

Phrases	Related Objects
Move his arm	--
Hide his face	Hand, napkin, or tissue
Stomp his feet	--
Comb his hair	Comb or brush
Hold his hand	--
Pat his leg	--
Wipe his mouth	Napkin or tissue
Blow his nose	Tissue or napkin
Brush his teeth	Toothbrush
Pull his toes	--
Touch his tongue	--
Find his shoe	Shoe

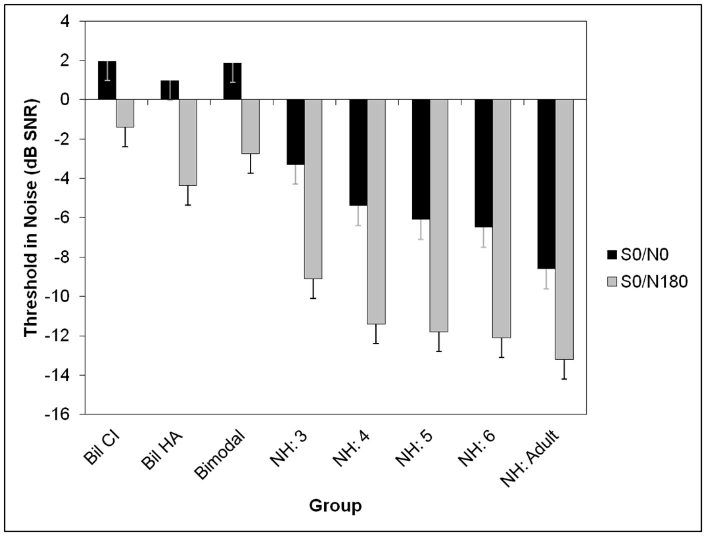

Figure 3. Average speech-in-noise thresholds in dB signal-to-noise ratio (SNR) of participants hearing aids (HA) and cochlear implants (CI) as well as those with with normal-hearing (NH) sensitivity obtained using the Phrases in Noise Test (PINT) in conditions with spatially coincident (S0/N0) and spatially seperated (S0/N180) sound sources. *Note*. Normal hearing data from Schafer et al. (in press); Bil=bilateral.

Teacher Questionnaire

Twenty one teachers chose to return completed Preschool S.I.F.T.E.R. questionnaires, and the average results for the three separate groups are provided in Table 3. When comparing the average ratings for the bilateral CI group in Table 3 to the normal range of Preschool S.I.F.T.E.R. ratings on the left side of the table, most children had no at-risk ratings, with the exception of an average at-risk-teacher rating for the content area of communication. When examining the individual data from each participant in the bilateral CI group, only the communication content area resulted in at-risk ratings from at least half (67%) of the teachers.

The children with bilateral hearing aids showed a different pattern of average ratings (Table 3) as compared to those using bilateral CIs. The average teacher results revealed at-risk ratings for the areas of attention and communication. Examination of the individual ratings for each participant with bilateral hearing aids showed that at least half teachers reported at-risk ratings for the categories of socially-appropriate behavior and attention. On average, the children using bimodal stimulation showed at-risk ratings for socially-appropriate behavior (2 of 4 teachers), attention (2 of 4), and communication (3 of 4).

Relationships Between Questionnaire Ratings and Speech Recognition

To examine the strength of the relationship between levels of educational risk and speech recognition performance in noise, planned Pearson product-moment correlation coefficients were computed between ratings on the Preschool S.I.F.T.E.R. and speech-in-noise thresholds in each condition for the bilateral CI and the bilateral hearing aid groups. Correlation coefficients were not calculated for the bimodal stimulation group given the small sample size (n=4). The results of these analyses are shown in Tables 4 and 5, and the significance of relationships was determined with a paired *t*-test.

Several medium (> $r = \pm .3$) and strong correlation coefficients (> $r = \pm .5$) were found and represent significant relationships ($p < .05$). For the bilateral CI group, the correlation coefficients between the Preschool S.I.F.T.E.R. ratings and speech recognition in noise yielded medium to strong, significant correlation coefficients between speech recognition in the S0/N0 conditions (Table 4) for expressive communication (r = -.55), academics (r = -.61), attention (r = -.75), communication (r = -.46), class participation (r = -.67), and social behavior (r = -.33). Note that all correlation

Table 3. Average Ratings on Teacher Preschool S.I.F.T.E.R.

	S.I.F.T.E.R. Rating (normal range)	Bilateral CIs (SD) n=9	Bilateral HAs (SD) n=8	Bimodal (SD) n=4
Primary Areas	Expressive Comm (14-30)	16.6 (7.5)	15.3 (2.4)	19.3 (4.0)
	Soc-App Behavior (12-20)	13.8 (3.7)	12.1 (6.7)	11.5 (3.0)
Content Areas	Preacademics (7-15)	9.9 (2.6)	9.0 (2.5)	9.0 (0.8)
	Attention (9-15)	9.8 (3.4)	7.4 (3.2)	8.0 (1.8)
	Comm (9-15)	7.9 (4.8)	8.4 (2.5)	8.5 (3.0)
	Class Participation (7-15)	10.1 (2.2)	9.5 (2.1)	11.5 (2.5)
	Social Behavior (9-15)	10.6 (2.5)	9.6 (3.1)	9.3 (3.3)

Note. CIs=cochlear implants; Comm=communication; HAs=hearing aids; S.I.F.T.E.R.=Preschool Screening Instrument for Targeting Educational Risk; SD=Standard deviations; Soc-App=socially appropriate.

Table 4. Average Ratings on Parent and Teacher Preschool S.I.F.T.E.R. for the Bilateral Hearing Aid Group

	S.I.F.T.E.R. Rating (normal range)	Parent Ratings (SD) n=9	Teacher Ratings (SD) n=8	Correlation Coefficient
Primary Areas	Expressive Comm (14-30)	14.9 (5.1)	15.3 (2.4)	.55
	Soc-App Behavior (12-20)	11.1 (5.3)	12.1 (6.7)	.87
Content Areas	Preacademics (7-15)	9.7 (2.1)	9.0 (2.5)	.60
	Attention (9-15)	7.0 (2.1)	7.4 (3.2)	.50
	Comm (9-15)	7.4 (3.4)	8.4 (2.5)	.65
	Class Participation (7-15)	8.2 (3.0)	9.5 (2.1)	.59
	Social Behavior (9-15)	8.3 (2.3)	9.6 (3.1)	.81

Note. S.I.F.T.E.R.=Preschool Screening Instrument for Targeting Educational Risk; SD=Standard deviations; Comm=communication; Soc-App=socially appropriate. Correlation coefficients were calculated with Pearson's.

coefficients suggest that better teacher ratings in these areas were related to better speech recognition in noise performance. In the bilateral hearing aid group correlation coefficients (Tables 4 and 5) between teacher ratings and speech recognition in the S0/N0 or S0/N180 condition suggest significant, medium relationships for attention (S0/N180, $r = -.40$), class participation (S0/N0, $r = -.34$), and social behavior (S0/N180, $r = -.37$).

Discussion

Can the PINT Help to Determine Educational Need?

The primary goal in developing the PINT was to create a tool that was valid, reliable, and sensitive enough to identify young children with hearing loss who may be at risk for listening, learning, and educational problems (i.e., educational need) in the classroom due to poorer-than-normal speech recognition performance. A sensitive speech recognition measure has a clear purpose, identified populations for which test may be used, high validity and reliability, and defined procedures for administration, scoring, and interpretation (Elkins, 1984; Mendel & Danhauer, 1997; Schafer, 2010). Factors relating to the sensitivity of the PINT have been addressed in previous investigations (Schafer, 2010, Schafer et al., in press; Schafer & Thibodeau, 2006). However, the results of the present study provide evidence to support the sensitivity as well as the efficacy and effectiveness of using the PINT for determining educational need in three different ways: (1) the significant differences detected between listening conditions in this study, (2) the significant correlations between PINT results in this study and Preschool S.I.F.T.E.R. ratings, and (3) the comparison of data in this study to previous data from children with normal-hearing sensitivity (Schafer et al., in press), which is provided in a paragraph below.

First, the sensitivity and efficacy of the PINT for determining educational need was shown through the average results within each separate group, which revealed significantly better performance in the listening condition with spatial separation of the speech and noise sources (S0/N180) over the condition with spatially coincident stimuli (S0/N0). In other words, this test was sensitive for detecting significant differences in conditions that, according to a previous study in normal-hearing children (Schafer et al., in press), are expected to produce different results. The average speech-in-noise thresholds in each condition, shown in Figure 3, may appear particularly low (i.e., good) for children with hearing loss. However, this test is essentially closed set following the familiarization procedure, and children are likely to identify a whole phrase by only hearing one word of the phrase. In addition, as discussed in a paragraph below and shown in Figure 3, these thresholds are substantially worse than what was measured in children with normal-hearing sensitivity.

This significant difference between the S0/N0 and S0/N180 conditions suggests the presence of SRM for children with bilateral CIs, bilateral hearing aids, and bimodal stimulation, and all three groups achieved similar amounts of SRM. The average data among groups was not statistically compared because of the expected group differences and varying sample sizes. In comparison to previous studies that reported variable SRM in children using bilateral CIs, bimodal stimulation, or hearing aids (Ching et al., 2010; Litovsky et al., 2006; Van Deun et al., 2010), all three groups in the present study achieved SRM ranging from an average of 3.4 dB to 5.3 dB. This finding is similar to the 3 dB SRM achieved by the children using bilateral CIs in the Van Deun et al. (2010) study. The larger SRMs obtained in the present study may be partially related to greater separation of the noise source (from 0 to 180 degrees) relative to the location of the noise in previous studies (from 0 to ± 90 degrees).

Second, the effectiveness of the PINT for determining educational need was supported with the significant correlations that were computed between the PINT thresholds and the teacher Preschool S.I.F.T.E.R. ratings. For the children with bilateral CIs, performance in the S0/N0 correlated significantly with most areas on the teacher

Table 5. Average Ratings on Parent and Teacher Preschool S.I.F.T.E.R. for the Bimodal Stimulation Group

	S.I.F.T.E.R. Rating (normal range)	Parent Ratings (SD) n=6	Teacher Ratings (SD) n=4	Correlation Coefficient
Primary Areas	Expressive Comm (14-30)	20.5 (6.7)	19.3 (4.0)	.39
	Soc-App Behavior (12-20)	13.8 (4.2)	11.5 (3.0)	.62
Content Areas	Preacademics (7-15)	10.8 (2.2)	9.0 (0.8)	-.43
	Attention (9-15)	10.0 (3.3)	8.0 (1.8)	.48
	Comm (9-15)	10.2 (3.4)	8.5 (3.0)	.47
	Class Participation (7-15)	11.2 (3.3)	11.5 (2.5)	.08
	Social Behavior (9-15)	10.2 (3.4)	9.3 (3.3)	.49

Note. S.I.F.T.E.R.=Preschool Screening Instrument for Targeting Educational Risk; SD=Standard deviations; Comm=communication; Soc-App=socially appropriate. Correlation coefficients were calculated with Pearson's.

questionnaire, which suggests that communication, academics, class participation, and social behavior may be related to the child's ability to recognize auditory stimuli in the presence of background noise. The correlations for the bilateral hearing aid group yielded slightly different results. First, no medium or strong correlations were detected between PINT thresholds and the Preschool S.I.F.T.E.R. in the areas involving academics or communication. Instead, the PINT thresholds for the group with bilateral hearing aids significantly correlated with the areas of attention, class participation, and social behavior. The differences between groups may represent the better unaided hearing thresholds for the bilateral hearing aid group relative to the bilateral CI group. Although not reported, it is highly likely that children in the bilateral CI group had unaided hearing thresholds in the severe-to-profound range while children in the bilateral hearing aid group had a wide range of unaided hearing loss configurations (e.g., mild-to-severe; moderate; moderate-to-severe). In addition, although the CI is expected to provide thresholds in normal-to-mild hearing loss range, the fidelity (e.g., spectral information, fine temporal structure, etc.) of the signal from the CI is limited when compared to what is provided through traditional hearing instruments and acoustic hearing. Overall, the most relevant finding for these analyses was the multiple significant relationships detected between PINT performance and Preschool S.I.F.T.E.R. primary and content areas, which provides empirical evidence that performance in the classroom may be related to the child's ability to recognize speech from the primary talker or teacher.

Finally, the sensitivity of the PINT for determining educational need may be shown by comparing the results in the present study to the average normative data in Figure 3 from young children with normal-hearing sensitivity in a previous investigation (Schafer et al., in press). In Figure 3, when comparing the data from the present study to the previous study, it is evident that the children with hearing loss had substantially poorer average thresholds regardless of the binaural device configuration. To examine whether or not these substantial differences were significant, each subject's PINT threshold in the S0/N0 and S0/N180 condition and SRM was compared to the 95% confidence interval from the normal-hearing children in the previous study with the same chronological age and listening age (i.e., age at testing minus age at CI or hearing aid fitting). According to these comparisons, 93% of children (27 of 29) in the present study (all but two with bilateral hearing aids in the S0/N180 condition) had significantly ($p < .05$) poorer PINT thresholds in the S0/N0 and S0/N180 conditions as compared to the normal-hearing children with the same chronological age. Even when accounting for the child's listening age, which represents the age at the hearing aid fitting or the receipt of the CI, the majority of subjects were outside the normal range for the S0/N0 condition (28 of 29 subjects) and S0/N180 condition (26 of 29 subjects). These comparisons yield noteworthy results because they provide strong evidence that these children do not obtain speech recognition performance in noise that is similar to normal-hearing peers.

The comparisons of SRM between studies yielded different results across the groups. Two of 13 children with bilateral CIs showed higher-than-normal SRM for chronological and listening age, six of ten children with bilateral hearing aids had normal (n=4) or higher-than-normal SRM for chronological and listening age, and two of six children with bimodal stimulation displayed higher-than-normal SRM for chronological and listening age. When examining the cause of the higher SRM in these children, it appears that half of them had poorer S0/N0 performance than other children within their group while the other half had surprisingly good S0/N180 performance relative to the other subjects, which led to a larger discrepancy between the two conditions and the higher SRM. Differences in SRM may be attributed to the longer duration of hearing aid use in the bilateral CI or bimodal groups as well as the degree of hearing loss in the children's non-implant ears.

Overall, the comparisons between studies support sensitivity of the PINT for detecting the expected and significant differences between children with hearing loss and those with normal-hearing sensitivity. In addition, it is interesting to note that despite spatial separation of speech and noise sources in the S0/N180 condition, children with CIs and hearing aids do not perform within normal limits as compared to age-matched peers. Therefore, preferential seating alone, or spatial separation of speech and noise sources, cannot address the deleterious effects of noise on the speech recognition ability of children with hearing loss. In order to achieve performance similar to normal-hearing peers, these children will likely require personal FM systems to consistently improve the SNR as well as classroom accommodations, such as note takers, printed announcements and instructions, captioned movies, and the use of teacher strategies to control noise levels (e.g., noise thermometer poster placed on classroom wall where teacher can indicate to the class with a gesture or stick-on symbol when the noise level is too high).

Use of PINT in Real Classroom Settings

The feasibility and appropriateness of using the PINT in a real classroom setting was confirmed in a previous investigation involving 68 children with normal hearing sensitivity (Schafer et al., in press) and is further supported with the results from 29 young children with CIs and/or hearing aids in the present study. Although the children in the current study were tested in several different rooms, the varying acoustics did not appear to influence results because a significant SRM was measured in all three groups. In fact, as previously mentioned, 10 children had higher-than-expected SRM as compared to normal-hearing peers. As a result, the PINT may be used in a small room, as done in this study, or in the child's classroom. Testing in the child's actual classroom would represent performance in his or her customary environment, which is more realistic and also is required according to the Individuals with Disabilities Education Act (2004) during a functional evaluation for assistive technology.

Regardless of the type of room, educational audiologists will need to consider three aspects for testing in a classroom: equipment, classroom acoustics, and interpretation. First, in the current and previous study (Schafer et al., in press), children completed two test conditions, S0/N0 and S0/N180, in classroom settings with the following equipment: a stereo with detachable loudspeakers, a CD player, and a sound level meter. However, the equipment used to present the PINT may be modified slightly for use by educational audiologists in real classroom settings. Our laboratory recently adopted a less cumbersome approach to presenting PINT stimuli through the use of a laptop computer with a CD drive, high-quality computer speakers (e.g., Bose Companion 2, Series II Multimedia Speaker System), and an audio extension cable to allow for a distance of 6 feet between the speakers. The stimuli may be calibrated with a simple sound level meter (e.g., Radio Shack Digital Display Sound Level Meter) or with software on a smartphone (e.g., dB Volume Meter for iPhone).

The second consideration to using the PINT is the acoustics of the classroom where the testing will be conducted. For the most part, the rooms used in the present and previous studies were ideal environments that met the acoustic guidelines set forth by ASHA (2005) and ANSI (2010). As stated in the introduction, however, typical classrooms rarely meet ASHA and ANSI recommendations for acoustics (Knecht et al., 2002). As a result, when using the PINT in a typical classroom, poorer-than-normal performance may be related partially to the acoustics as well as the child's hearing loss, which are both important factors to consider during an evaluation for educational need for an FM system. Rooms with excessive noise or a room with longer reverberation times would negatively influence performance. According to previous research (Neuman et al., 2010), performance only decreased by approximately 1 dB with reverberation increasing from 0.3 to 0.6 seconds, with an additional 1 dB change from 0.6 to 0.8 seconds. It is important to note, however, that when compared to children with normal hearing, those with hearing loss have significantly poorer speech recognition to begin with and are more affected by increased reverberation time, with changes of approximately 1 to 2 dB from 0.3 to 0.6 seconds and 0.6 to 0.8 seconds (Neuman et al., 2010). Therefore, in larger, typical-sized mainstreamed classrooms with reverberation times ranging from 0.5 to 1.0 seconds (Knecht et al., 2002), the audiologist might expect performance to worsen in children with hearing loss by 2 to 3 dB SNR on the PINT relative to performance that would be measured in a smaller room like the one used in this study.

Finally, if used in a child's real classroom, the educational audiologist will need to be able to interpret the PINT scores to determine the presence of educational need relative to normal-hearing peers. When considering a child's individual PINT threshold in dB SNR, this performance represents the SNR where the child will act out 50% of the closed-set phrases correctly. In a real listening situation in a classroom, audiologists strive to provide children with hearing loss approximately 100% correct speech recognition in noise. Therefore, assuming a linear relationship between performance and SNR, as shown in previous investigations (Jerger & Jerger, 1982; Plomp & Mimpen, 1979), the child's dB SNR will need to be at least doubled to predict the SNR where the child could achieve approximately 100% correct on an essentially closed-set task in a classroom. For example, if a child requires a +2 dB SNR to obtain 50% correct performance, he would need at least a +4 dB SNR to hear most of what the teacher says. However, this estimate does not take into account other aspects involved in speech recognition in noise including (1) reverberation, (2) language comprehension, (3) working memory, (4) attention, and (5) effects of closed- vs. open-set tasks. Of course, most classroom instruction and activities involve open-set vocabulary and tasks. No previous data was found that examined the difference between closed-set versus open-set speech recognition performance in children; however, we estimate that open-set tasks will require a better SNR. When using the example discussed earlier in this paragraph, and then adding an additional 1 dB to account for each of the five other child-related factors, the investigators hypothesize that this child would require at least a +9 dB SNR to hear most of the information from the teacher in a classroom environment.

Perhaps a simpler interpretation of a PINT threshold is to calculate the difference score from the average performance of children in the normal hearing study (Schafer et al., in press). For example, Participant 14, who was 6;2 years and used bilateral hearing aids, had a PINT threshold of +3 dB SNR in the S0/N0 condition and -5.25 dB SNR in the S0/N180 condition. Children from the previous study, who were 6-years old and had normal-hearing sensitivity, had an average performance of -6.5 dB SNR (95% confidence interval = 0.7 dB) in the S0/N0 condition and -12.1 dB SNR (95% confidence interval = 2.0 dB). As a result, Participant 14 had deficits of 9.5 dB SNR in the S0/N0 condition and 6.9 dB SNR relative to normal-hearing peers, which represents significantly poorer performance in both conditions. If these results were obtained by an educational audiologist in a real classroom setting, they would certainly warrant a referral to special education for a HAT evaluation. This information about interpreting PINT performance must be carefully explained to parents, teachers, administrators, and other school personnel.

To provide a comparison to children with normal-hearing sensitivity, the 95% confidence intervals for PINT thresholds in 3-, 4-, 5-, and 6-year old children with normal-hearing sensitivity are provided in a previous investigation (Schafer et al., in press). In addition, the audiologist will be able to compare a child's performance to the performance of children with CIs and hearing aids in this study to determine if it is similar.

Study Limitations

Limitations in this study are related to (1) the multiple rooms where children were tested, (2) the various devices used by the children, and (3) the characteristics of the PINT stimuli. First, as explained in the methods section, multiple rooms were utilized for testing to increase the sample size in each group. Given the similar acoustics of the rooms in this study, it is highly unlikely that the use of different rooms influenced PINT performance significantly. Varying unoccupied noise levels across the rooms would not have affected performance because the testing was conducted in background noise, and the calibration procedures used for the PINT accounted for the existing unoccupied noise sources. In addition, reverberation times were not of concern because all rooms had reverberation times of less than 0.4 seconds. Previous investigations on the effects of reverberation times on young children's speech recognition performance suggest minimal changes (i.e., 1 dB) in performance in rooms ranging from 0.3 to 0.6 seconds (Neuman et al., 2010). The PINT uses a 3-dB step size; therefore, a change in performance by 1 dB, caused by an increase or decrease in reverberation time, would not result in a different dB SNR obtained on the PINT scoring form.

Second, children in each group were using different CIs and hearing aids; therefore, the use of various devices may have contributed to the variability within the three groups of children. The children with hearing aids may have been using different hearing aid prescriptive strategies, directional microphones, noise reduction technology, compression characteristics, and frequency-compression technology. The children using CIs from different manufacturers were definitely using different sound processing strategies, which determine how speech is coded in quiet and in noisy environments. In addition, the examiners had no way to determine the appropriateness of the fit of the CI or hearing aid. On the other hand, the data presented in this study represent realistic groups of children who are served at various hearing centers and are using bilateral CIs, bilateral hearing aids, and bimodal stimulation. Therefore, these results may be more generalizable to the population of children in the schools with these devices than groups of children selected based on specific device characteristics.

Third, the PINT stimuli cannot directly simulate the complex vocabulary level used in a classroom, the varying intensity of the teacher's voice, or the ever changing background noise level in a typical classroom. Because the PINT is an essentially closed-set task, some children likely identified a phrase correctly by only hearing one word. However, to produce a sensitive and reliable speech-in-noise test, the vocabulary was constrained, the intensities of the speech and noise were carefully controlled, and stimuli were adjusted (Schafer et al., in press). Despite the fact that the PINT may not directly predict speech recognition during classroom instruction, it does appear to predict classroom performance given the correlations in the present study between teacher ratings on the Preschool S.I.F.T.E.R. and PINT performance.

Finally, the results of the planned correlation analyses were somewhat limited due to the incomplete return rate for the teacher questionnaires (i.e., small sample size) and the within-group variability associated with ages, devices used by the children, and other child-related factors (e.g., duration of device use). When multiple correlations are calculated with small sample sizes, interpretation of correlation coefficients may be misleading due to the colinearity between the variables. Because of these limitations, the researchers only considered medium and strong correlation coefficients worthy of reporting in the text of the results section despite the fact that almost all relationships were significant according to *t*-tests (Tables 4 and 5).

Study Summary

According to the results in this investigation, the PINT is a feasible, sensitive, efficacious tool for assessing speech-in-noise thresholds in young children with CIs and hearing aids, and the PINT may be used to identify children who are at risk for listening difficulties and educational problems in the classroom. Pairing the PINT with a Preschool S.I.F.T.E.R. completed by the teacher may provide even more evidence regarding the child's level of functioning in the classroom. The three groups of children in this study, including those using bilateral CIs, bilateral hearing aids, and bimodal stimulation, showed better speech recognition performance in noise in the listening condition with spatial separation of speech and noise sources as compared to a condition with speech and noise from the same location. These results suggest that, on average, children with these binaural listening arrangements are able to achieve significant SRM.

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Aided Speech Perception Testing Practices for Three-to-Six-Year Old Children With Permanent Hearing Loss

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Routine early identification and management of hearing loss in infants is relatively recent because newborn hearing screening has become a standard of care in the United States. More children are identified with hearing loss earlier and achieve age-appropriate speech and language skills. This means that younger children have the skills needed to participate in more challenging, open-set speech perception testing procedures. This study examined current practice patterns of pediatric audiologists to provide insight into how speech perception testing is being utilized to validate aided benefit for this population.

The present study used a cross-sectional survey design. The survey consisted of 23 questions that addressed four aspects of audiology practice: (1) practice demographics, (2) speech perception tests used based on age (i.e., 3-year-olds, 4-year-olds, 5-year-olds, 6-year-olds), (3) test variables and conditions, and (4) communication and collaboration with speech-language pathologists and educators. The survey was completed anonymously online. One hundred and forty-five audiologists from 37 states completed the survey (14% return rate). One-quarter of the pediatric audiologists who responded who work with preschool-aged children with hearing loss do not include aided speech perception testing. Audiologists reported selecting three tests most frequently and using monitored live voice more often (82%) than recorded speech. In addition, the presentation level selected varied among providers. Further research is needed to better provide guidance for testing decisions and understand how test parameters contribute to speech perception performance for preschool-aged children with hearing loss.

Introduction

Hearing loss is now routinely identified at two to three months of age in the United States as a result of universal newborn hearing screening (White, Forsman, Eichwald, & Muñoz, 2010). This has an impact on all aspects of service delivery for young children with hearing loss, and given appropriate access to audiological and early intervention services, many children have the potential to follow a typical developmental trajectory (e.g., Robbins, Koch, Osberger, Zimmerman-Phillips, & Kishon-Rabin, 2004). Pediatric audiologists have a central role throughout the process, from identification to intervention. Speech perception testing can provide audiologists with valuable information about how a child is using hearing to discriminate and comprehend speech and language. However, assessment of benefit from hearing technology using aided speech perception measures for preschool-aged children and related interdisciplinary collaboration are often underutilized. As more children are identified with hearing loss earlier and achieve age-appropriate speech and language skills, preschool children (i.e., children ages 3- to 5-years-old) have the ability to participate in more challenging speech perception testing procedures. This study examined current practice patterns of pediatric audiologists to provide insight into how speech perception testing is being utilized to validate benefit for this population.

For children who are learning spoken language and use hearing technology, audiology services are fundamental to successful intervention. In fact, decisions made regarding hearing technology can positively or negatively impact child outcomes. Pediatric audiologists have a responsibility to provide comprehensive evidence-based services, and practice guidelines are available (American Speech Language and Hearing Association [ASHA], 2004; American Academy of Audiology [AAA], 2003, 2008; Joint Committee of Infant Hearing [JCIH], 2007). Even though guidelines are available, there are factors that influence the field (e.g., age of identification, changes in hearing technology) faster than guidelines can be updated. For this reason, clinical judgment and professional accountability for remaining current in pediatric hearing issues are also critical components when making decisions for each individual child.

Many audiologists who work with children with hearing loss do not provide aural habilitation services; however, they are responsible for measuring outcomes and validating benefit over time through ongoing audiological monitoring services. One way to measure benefit is through speech perception testing. These measures offer audiologists an opportunity to measure functionality of a child's communicative abilities (Blamey, 2001). Speech perception has been positively correlated to speech and language performance in school-age children (Blamey, et al., 2001; Eisenberg, Martinez, Holowecky & Pogorelsky, 2002; Spencer, Tye-Murray, & Tomblin, 1998; Stelmachowicz, Pittman, Hoover & Lewis, 2002; DesJardins, Ambrose, Martinez, & Eisenberg, 2009) and, more recently, preschool-age children. For example, in a recent study by Ambrose, Fey, and Eisenberg (2012), preschoolers' speech perception scores as measured by the Play Assessment of Speech Pattern Contrasts (PLAYSPAC; Boothroyd, Eisenberg, & Martinez, 2006; Eisenberg, Martinez, & Boothroyd, 2007) were significantly positively related to speech production, language comprehension and expression, and early literacy measures (i.e., phonological awareness and print knowledge). This relationship provides audiologists with a rationale to include speech perception measures as part of their validation practices for young children.

Regrettably, direction provided by practice guidelines related to validation is minimal. For example, the AAA (2003) pediatric amplification guideline offers recommendations of certain speech perception tests that can be considered; however, there are no recommendations related to test conditions and variables (e.g., presentation level, mode of presentation). The guideline also indicates that monitoring appointments are recommended every three months for the first two years following the fitting, then every four to six months, and periodic validation should be provided. Similarly, the ASHA (2004) guideline recommends speech perception as part of the assessment protocol for children who are developmentally 25 to 60 months of age. The recommendations include tests to consider but no recommendations related to test conditions. Because of a lack of systematic recommendations related to outcome evaluations, the Pediatric Audiological Monitoring Protocol (PedAMP) was developed (University of Western Ontario, 2012), and while this resource offers valuable direction, its scope does not include aided speech perception testing.

Prior to advances in newborn hearing screening, the average age of identification of hearing loss was between 2 ½ and 3 years of age (ASHA, 2012), and audiologists relied on closed-set speech perception tasks (e.g., picture identification from a limited set of items) due to limitations of a child's intelligibility or vocabulary skills. Today, because children are identified with hearing loss at younger ages and are enrolled in early intervention services, they often have the potential to develop speech and language skills commensurate with their age-matched hearing peers. With that in mind, it is important for audiologists consider use of open-set speech perception tests that are sensitive enough to measure the most advanced level of the child's speech perception development, and, more importantly, functional communicative performance. As audiologists work with increasing numbers of children from cultural and linguistically diverse backgrounds, it is important that they have access to speech perception tests that assess a child's development in their native language to maximize the sensitivity obtained from these measures.

Optimizing outcomes for children with hearing loss involves multidisciplinary collaboration and effective teaming among the parents and professionals involved for each child. Speech perception testing offers an integrated look at the relationship between speech perception and speech production and can also be an indicator of later language development (Blamey, et al., 2001). When audiologists and speech-language pathologists collaborate regarding results from these measures, they are better able to analyze the nature of the errors and to determine the intervention path that best addresses the child's needs. This path may include increased or different strategies in intervention, modifications to a child's hearing technology, and/or consideration of an alternate hearing device.

The purpose of this study was to better understand test protocols and procedures that are currently being used by pediatric audiologists who work with 3- to 6-year-old children who have permanent hearing loss.

Methods

The study used a cross-sectional survey design. A pediatric audiologist and a speech-language pathologist developed the survey and piloted the survey with nine audiologists in Utah to determine question clarity. The Utah State University Institutional Review Board approved the study methods. The survey consisted of 23 questions that addressed four aspects of audiology practice: (1) practice demographics, (2) speech perception tests used based on age (i.e., 3-year-olds, 4-year-olds, 5-year-olds, 6-year-olds), (3) test variables and conditions, and (4) communication and collaboration with speech-language pathologists and educators. The survey was completed anonymously online.

Data Collection

Pediatric audiologists were recruited to participate through children's hospitals, university programs, and the Educational Audiology Association membership. In January 2012, 1,072 audiologists were sent an invitation to complete the survey; a postcard that included the website address to complete the survey was mailed through the U.S. postal service for those who did not have an accessible email address (94 audiologists). A reminder was sent two weeks after the initial mailing.

Data Analysis

Results from the surveys were coded in an Excel file and checked for accuracy and completeness. Data were analyzed using SPSS to calculate descriptive statistics, including frequencies and percentages.

Results

One hundred and forty-five audiologists from 37 states completed the survey (14% return rate). Twelve of the respondents were not included in the analysis because they reported that they did not work with 3- to 6-year-old children with permanent hearing loss. Of the remaining 133 respondents, 32 (24%) reported that they did not perform aided speech perception testing. The reasons the audiologists reported that speech perception testing was not provided included that the children were followed by their private audiologist, there was not enough time to complete testing, they used real ear measures, and they did not have sound field testing capabilities. Therefore, analyses were conducted with the 101 respondents who provided aided speech perception testing.

Practice Demographics

Audiologists were asked about their primary work setting, how long they had been practicing audiology, and to report on various aspects of testing 3- to 6-year-olds with permanent hearing loss (see Table 1). The majority of respondents worked in public schools and hospitals. The remainder of the respondents were grouped into a category referenced as "other" in Table 1 and reported working in the following settings: private practice (*n* = 4), State School for the Deaf (*n* =5), University clinic (*n* = 9), non-profit center (*n* =1), state-affiliated clinic (*n* =1), private school (*n* =1), and more than one setting was reported (*n* = 10). Eighty-three percent of the respondents had been working eight or more years.

Audiologists reported that the children they follow used the following types of hearing technology: hearing aids only (31%), cochlear implants only (3%), and both hearing aids and cochlear implants (66%). Almost half (49%) of the respondents reported following over 15 children on a regular basis and reported that this population made up less than a quarter of their overall schedule during the previous month. Audiologists were also asked how often they typically monitor hearing for these children and how often they include aided speech perception testing. The majority (66% and 69%, respectively) reported every six months or annually for both questions. One-quarter (25%) of the respondents reported other monitoring schedules, such as they make decisions specific to each child's needs, that an audiologist at another facility does the testing, or that they complete testing when they receive a referral. Other answers for testing aided speech perception included at every visit, whenever hearing technology is checked, and variable schedules.

Table 1. Practice Demographics of Audiologists Who Perform Aided Speech Perception Testing for Children 3- to 6-years-old With Permanent Hearing loss

	Public School 40% (*n* = 40)	Hospital 30% (*n* = 30)	Other 31% (*n* = 31)
Years in practice			
<3 years	2 (05)	4 (13)	4 (13)
3 to 7 years	2 (05)	4 (13)	2 (06)
8 to 15 years	5 (13)	10 (34)	4 (13)
>15 years	30 (77)	12 (40)	21 (68)
Children followed on a regular basis			
1 to 5	12 (30)	2 (07)	15 (48)
6 to 10	6 (15)	7 (23)	2 (06)
11 to 15	3 (07)	2 (07)	3 (10)
> 15	19 (48)	19 (63)	11 (35)
Percent of practice during previous month			
1 to 25%	31 (78)	15 (50)	23 (74)
26 to 50%	6 (15)	6 (20)	3 (10)
51 to 75%	7 (08)	6 (20)	2 (06)
76 to 100%	0	3 (10)	3 (10)
Routine audiological monitoring			
Annually	8 (20)	2 (07)	5 (16)
Every 6 months	20 (50)	22 (73)	9 (29)
Every 3 months	1 (02)	2 (07)	3 (10)
As needed	3 (08)	0	1 (03)
Other	8 (20)	4 (13)	13 (42)
Aided speech perception testing			
Annually	12 (30)	7 (23)	7 (23)
Every 6 months	20 (50)	15 (50)	9 (29)
Every 3 months	1 (2.5)	2 (07)	4 (13)
As needed	1 (2.5)	0	1 (03)
Other	6 (15)	6 (20)	10 (32)

Speech Perception Testing

A variety of speech perception tests were used for each age (i.e., 3-, 4-, 5-, and 6-year-olds), and the preferences shifted based on age (see Table 2). The most frequently used tests for the 3-, 4-, and 5-year-olds were the Phonetically Balanced Kindergarten Lists (PBK; Haskins, 1949), the Word Intelligibility by Picture Identification Test (WIPI; Ross & Lerman, 1971), and the Northwestern University Children's Perception of Speech (NU-CHIPS; Elliott & Katz, 1980). For the 6-year-olds, the most frequently used tests were the PBK, WIPI, and Bamford-Kowal-Bench Speech-in-Noise sentences (BKB-SIN; Etymōtic Research, 2005). Other tests and/or tasks reported included asking children to point to body parts, Mr. Potato Head task (Robbins, 1994), speech recognition threshold, Common Phrases (Robbins, Renshaw, & Osberger, 1995), Pediatric Speech Intelligibility test (PSI; Jerger & Jerger, 1984), Test of Auditory Comprehension (TAC; Trammell, 1976), Plurals test (Glista & Scollie, 2012), Ling Six Sound Test (Ling, 2002), the Speech Perception Instructional Curriculum and Evaluation (SPICE; Moog, Biedenstein, & Davidson, 1995) curriculum, and the Glendonald Auditory Screening Procedure (GASP; Erber, 1982). When test choice was compared by age for the two most common work environments (i.e., hospitals and public schools) responses were similar. For example, for the PBK, 27% of audiologists in hospitals and 39% in public schools used this test for 3-year-olds, and 70% of audiologists in hospitals and 65% in public schools used this test for 5-year-olds.

For each test, audiologists were asked how many words/ sentences they typically present (i.e., full list, half list, other) and if the stimuli are presented using monitored live voice (MLV) or with a recording (see Table 2). For the tests most frequently used, audiologists reported using a full list for the WIPI and BKB-SIN (one list pair) and a half list for the PBK and NU-CHIPS. For all tests except the BKB-SIN, the majority of the audiologists reported presenting the words using MLV.

Test Variables and Conditions

Several factors are considered when deciding which speech perception test to use. Audiologists reported considering the following: language level (*n* = 85, 84%), developmental level (*n* = 85, 84%), speech intelligibility (*n* = 78, 77%), primary language (*n* = 60, 59%), chronological age (*n* = 54, 53 %), and other factors (*n* = 12, 11%). Other factors audiologists considered were attention skills, child's cooperativeness, whether the child has behavior issues, activity level/state, previous tests used and outcomes, child's temperament on a particular day, auditory language age, listening age, maturity, audiologist's personal judgment and impression of the child.

Audiologists were asked what test conditions they typically use when assessing speech perception. The most common condition was in quiet at an average conversational speech level (*n* = 94, 93%). The second most common condition was testing in noise at an average conversational speech level (*n* = 72, 71%), but only about one-third test at a soft speech level (*n* = 36, 35%). Other conditions reported (*n* = 11, 10%) were both quiet and noise, auditory versus auditory visual, with/without frequency-modulated (FM) system, and soft speech with equivalent noise. For each of the three conditions (i.e., average conversational speech level in quiet and in noise, and soft speech level), most respondents performed the assessment binaurally only. For an average conversational speech level in quiet, approximately one-third performed the assessment binaurally and for each ear separately (see Table 3 on page 10).

The levels audiologists reported performing testing for average conversational speech in quiet ranged from 30 to 65 dB HL (*n* = 91); the most frequently reported level was 50 dB HL (42%). When testing in noise at an average conversational speech level, audiologists reported presenting speech at levels ranging from 40 to 70 dB HL (*n* = 61); the most frequently reported level

Table 2. Frequency of Use of Speech Perception Tests, Number of Words Presented, and Mode of Presentation for Children by Age

Test		3 Years	4 Years	5 Years	6 Years
ESP		31	17	8	7
	Whole List (Half List)	21 (2)	12 (1)	7 (0)	6 (0)
	MLV (Recorded)	27 (3)	14 (2)	8 (0)	7 (0)
PBK		43	57	73	64
	Whole List (Half List)	2 (36)	5 (49)	8 (62)	12 (50)
	MLV (Recorded)	36 (6)	47 (10)	57 (13)	49 (13)
MLNT		8	10	12	10
	Whole List (Half List)	8 (0)	10 (0)	12 (0)	10 (0)
	MLV (Recorded)	5 (3)	6 (4)	8 (4)	8 (2)
LNT		11	13	14	16
	Whole List (Half List)	11 (0)	12 (0)	14 (0)	15 (0)
	MLV (Recorded)	6 (3)	9 (2)	10 (3)	12 (3)
WIPI		67	62	45	23
	Whole List (Half List)	51 (13)	49 (10)	37 (6)	20 (2)
	MLV (Recorded)	61 (6)	52 (5)	40 (3)	21 (1)
NU-CHIPS		54	43	30	20
	Whole List (Half List)	5 (44)	5 (36)	10 (19)	9 (9)
	MLV (Recorded)	43 (10)	34 (8)	24 (5)	15 (5)
HINT-C		7	8	12	17
	Whole List (Half List)	6 (0)	7 (1)	10 (1)	12 (3)
	MLV (Recorded)	5 (2)	5 (3)	5 (7)	5 (12)
BKB-SIN		8	11	17	25
	Whole List (Half List)	5 (1)	10 (1)	15 (1)	21 (1)
	MLV (Recorded)	2 (6)	2 (9)	3 (14)	7 (18)
CNC		4	4	5	13
	Whole List (Half List)	1 (3)	0 (3)	0 (5)	2 (10)
	MLV (Recorded)	3 (1)	1 (2)	1 (4)	7 (6)
Other		21	14	19	25

ESP = Early Speech Perception; PBK = Phonetically Balanced Kindergarten List; MLNT = multi-Syllabi Lexical Neighborhood Test; LNT = Lexical Neighborhood Test; WIPI = Word Intelligibility by Picture Identification; NU-CHIPS = Northwestern University Children's Perception of Speech; HINT-C = Hearing in Noise Test for Children; BKB-SIN = Bamford-Kowal-Bench sentences; CNC = Consonant-Nucleus-Consonant Test; MLV = monitored live voice for presentation of speech was 50 dB HL (48%). The signal-to-noise ratio (SNR) ranged from 0 to +20 dB; the most frequently reported SNR was +5 SNR (44%).

Approximately two-thirds of the audiologists reported marking the specific errors made during speech perception testing (*n* = 72, 71%). Open-ended responses were elicited to identify how audiologists use speech perception test results. Only one-quarter (24%) of the audiologists provided a response and reported a variety of ways in which speech perception test results were used: to validate the hearing aid fitting; to give feedback to speech-language pathologist, teacher, and parents; to help guide amplification adjustments; to monitor progress of vocabulary, performance and/or performance changes; as a basis for developing auditory goals; to compare to previous testing to see if improvement occurs or if a problem is evident; to advocate for the need for a FM system.

When the child's primary language was not English, speech perception testing was provided less frequently (*n* = 40, 39%). When testing was provided, it was most often done in English (*n* = 26, 65%), a few audiologists provided testing in the child's own language (*n* = 3, 7%), and some tested in both English and the child's primary language (*n* = 10, 25%). Audiologists reported that they used the following tests for children whose primary language was not English: Consonant-Nucleus-Consonant (CNC; Peterson & Lehiste, 1962), a picture identification task, WIPI, Early Speech Perception (ESP; Moog & Geers, 1990), Mr. Potato Head, Hearing in Noise Test - Children (HINT-C; Nilsson, Soli, & Gelnett, 1996), and NU-CHIPS. When another language was used during testing, audiologists reported that the language was Spanish or other languages as available through interpreters.

Communication and Collaboration

The extent of communication and collaboration with providers who work closely with the child (i.e., speech-language pathologist, deaf educator/teacher) varied from one audiologist to another (see Table 4). Approximately one-third of the audiologists (*n*=38, 38%) reported that they frequently or always obtain speech-language assessment scores from the speech-language pathologist, and approximately two-thirds of the audiologists share speech perception test results with the child's speech-language pathologist and teacher (*n* = 75, 74% and *n* = 69, 69%, respectively. Just under half (48%) of respondents reported that they collaborate with these professionals to interpret speech perception test results.

Table 3. Aided Speech Perception Test Conditions Used by Audiologists

Test Condition	N	Binaurally only	Each Ear Separately	Both Binaural and Separately
Average Conversation				
Quiet	94	42 (45%)	14 (15%)	37 (39%)
Noise	72	52 (72%)	3 (4%)	18 (25%)
Soft Speech	36	21 (58%)	6 (17%)	9 (25%)

Table 4. Percent of Time Information is Shared Between the Audiologist and the Speech-Language Pathologists (SLP) and Deaf Educator (DE)

	N	Never	Sometimes	Frequently	Always
How often does the SLP/DE communicate speech-language assessment scores to you?	99	17	44	28	10
How often do you share speech perception results with child's SLP?	101	3	23	36	39
How often do you share speech perception results with the child's teacher/educator?	100	7	24	33	36
How often do you collaborate with the SLP/DE to interpret speech perception results?	101	13	40	37	11

Discussion

Routine early identification and management of hearing loss in infants is relatively recent, as newborn hearing screening has become a standard of care in the United States. This survey of pediatric audiologists was conducted to understand practice patterns currently being utilized to validate performance of young children using hearing technology with speech perception measures. The survey results revealed a gap in practice related to assessment of aided speech perception for preschool-aged children. One-quarter of the pediatric audiologists who responded that work with preschool-aged children with hearing loss, do not include aided speech perception testing. When this testing is included, audiologists reported monitoring speech perception every six months to one year. The survey results revealed considerable variability among audiologists related to testing decisions (e.g., presentation level, test condition) that could make comparison of test results between sessions and across clinics challenging.

A number of variables go into test selection, and the majority of audiologists reported considering multiple factors when choosing a test (e.g., developmental level, language level). Even with these considerations, there were three tests that audiologists reported selecting most frequently (i.e., PBK, WIPI, and NU-CHIPS) for preschool-aged children. Of these tests, the PBK was the most commonly given test, and the only, open-set speech perception measure administered to preschool children. Because children with hearing loss are identified and fit early, more children are able to successfully participate in open-set testing at earlier ages. While closed-set tasks can be easier to control and score particularly in younger populations, they offer limited ability to measure a child's functional use or performance in every day communicative situations (Blamey et al., 2001). There is a need for more research examining performance of preschool children on open-set speech perception measures, such as the PBK.

Because there is a positive relationship between speech perception and speech-language measures, collaboration between a speech-language pathologist and audiologist is particularly important to effectively interpret results from open set speech perception tasks as they pertain to functional communication outcomes of young children. While the majority of audiologists consider speech intelligibility and language level as an important part of test selection, only 38% of audiologists regularly obtained speech-language results from a speech-language pathologist. Both speech-language pathologists and audiologists can benefit from communication about results on these assessments and can collaborate about how these results can be interpreted in terms of modifications of hearing technology and/or intervention plans. Because audiologists see children less often than speech-language pathologists, this type of collaboration can be particularly helpful for preparing for appointments. Speech-language pathologists can offer insights into a child's progress, concerns, and consistency of use. When results are shared, it is easier for both professionals to use the data to monitor progress and to ensure that the child is receiving maximum benefit from technology as well as demonstrating progress in speech production.

Speech perception can be measured in various conditions to validate abilities using hearing technology, including in quiet and noise, at an average conversational speech level and at a soft speech level. Survey results revealed that audiologists use a variety of intensity levels for each of those conditions, resulting in significant variability among audiologists even for the same condition. For example, when audiologists reported testing speech perception in quiet at an average conversational speech level, they indicated using intensity levels ranging from 30 to 65 dB HL. Practice guidelines do not indicate standard presentation levels, and this may contribute to this variability. Madell and Flexer (2008) provided specific recommendations for children regarding presentation levels and test conditions. Recommendations include testing in quiet at normal conversation speech (50 dB HL) and at soft conversational speech (35 dB HL), and testing in competing noise (4 talker babble) at normal conversational speech (50 dB HL) with a +5 signal-to-noise ratio (SNR) and with a 0 SNR and at soft conversational speech (35 dB HL) with a 0 SNR. However, research studies that provide information about performance expectations for preschool-aged children with hearing loss are not available. It should be noted that the purpose of the test influences decisions and is dictated by the information the audiologist is seeking. The current study did not investigate which tests audiologists used for testing in quiet versus noise; although, there are test selection considerations that should be taken into account. For example, if a test were not designed for testing in noise it may not be an appropriate test to select.

Practice guidelines also do not provide direction related to the mode of presentation for speech perception testing. Stimuli used to measure speech perception can be presented either MLV or recorded speech. In this sample, audiologists used MLV more often (82%) than recorded for the three most frequently used tests. There have been numerous publications indicating recorded presentation is the preferred practice and essential for reliability (Roeser & Clark, 2008); however, this has been addressed primarily for the adult population. Measurement of speech perception abilities using recorded speech allows for standardization and for the results to reliably be compared among test sessions and between clinics. Audiologists have reported preferring MLV because it provides greater flexibility and is quicker to administer. According to a national practice survey, 82% of audiologists reported using MLV as the mode of stimulus presentation for adults (Martin, Champlin, & Chambers 1998).

There were several limitations to the current study and the small sample size limits the ability to infer broader practice patterns. The survey was completed electronically, and most respondents were notified via email to request their participation. Participants were notified twice, and further attempts to solicit participant response were not made, which may have influenced the low response rate of 14%. However, the response rate is similar to other surveys of healthcare providers. For example, a survey of speech-language pathologists had a response rate of 19.6% (Kalkhoff & Collins, 2012), and two surveys of physicians (Grava-Gubins & Scott, 2008) and residents (Westfal, Burrowes, Shorter, & Wright, 2011) had response rates of 29.9 and 8.7% respectively. The survey was anonymous, and clarification of responses could not be attempted, which limited ability to interpret results. For example, some speech perception tests can be used as an open- or closed-set test (e.g., WIPI), and the option to indicate how the test was used was not provided in the survey. Similarly, audiologists were asked what criteria they used to select tests (e.g., developmental level, language level) but the survey did not explore how audiologists obtained this information.

Further research is needed to better understand how test parameters (e.g., presentation level, mode of presentation, use of open-set tasks) contribute to speech perception performance for preschool-aged children with hearing loss. Evidence-based protocols would enhance the audiologists' ability to use aided speech perception testing to estimate real-world listening skills and support the integration of evidence-based validation practices in routine care. Speech perception testing provides valuable information (Boothroyd, 2004, p. 292) "to distinguish capacity from performance, to guide decisions about the need for, and choice of, sensory assistance, to optimize adjustments of sensory devices, to assess the immediate outcome of sensory assistance, to guide decisions about habilitative interventions, to monitor and evaluate the success of that intervention, and in general, to promote evidence-based practice."

Conclusion

Audiologists are encountering a new population of young children with hearing loss, children who have had the benefits of early identification and intervention. Advantages to child development offered by this shift are significant and audiological practices to support and monitor children need to be sensitive, timely and appropriate. Further research on practices for this population is required to guide effective service provision for amplification validation using speech perception measures.

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Functional Listening Evaluation Performance in Children with Reading Difficulties

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Listening to a degraded speech signal over time can interfere with language development and learning in children with both language and reading disorders. Some may benefit from modifications that improve access to speech in the classroom. The Functional Listening Evaluation (FLE; Johnson & Von Almen, 1997), developed for assessing classroom listening ability in children with hearing impairment, examines how noise, distance and visual input may affect speech recognition in school. The FLE might also be useful in demonstrating the need for particular accommodations in children with normal hearing who experience reading difficulties. The FLE was administered to 41 children, aged seven to ten, who were diagnosed with language impairments affecting reading. The Fisher's Auditory Problems Checklist (Fisher, 1985) was given to participants' parents to differentiate children with and without listening difficulties. Using BKB sentences, speech recognition scores were obtained for both groups. When key-word scoring was applied, scores were high overall for all participants. With more rigorous verbatim scoring, the group with reported listening difficulties scored lower than the group without reported listening difficulties for all FLE conditions. Within each group, distant conditions yielded significantly lower scores than close conditions. Counter-intuitively, only the group without reported listening difficulties showed significantly decreased scores in the noise conditions. Absence of visual cues did not affect speech recognition for either group. The FLE was somewhat sensitive to listening difficulties noted by parents, and with modifications, may provide useful information about accommodations for children with normal hearing who are at risk academically.

Introduction

Children, even those with normal hearing, need a more favorable listening environment and a clearer signal to perceive speech optimally than do adults (Eisenberg, Shannon, Martinez, Wygonski, & Boothroyd, 2000; Elliott, 1979; Stelmachowicz, Hoover, Lewis, Kortekaas, & Pittman, 2000; Stuart, 2008). Research has identified speech perception as an area of difficulty that adversely affects not only children with hearing impairment but also children identified with both language and reading impairments with no hearing deficit (Bishop & McArthur, 2005; Bradlow, Kraus, & Hayes, 2003; Bradlow et al., 1999; Fraser, Goswami, & Conti-Ramsden, 2010; Joanisse, Manis, Keating, & Seidenberg, 2000; Mody, Studdert-Kennedy, & Brady, 1997; Nittrouer, 2002; Vandermosten et al., 2011). Many children with both language and reading impairments are known to experience difficulty perceiving and differentiating between the rapidly occurring or changing components of speech (Bishop, Adams, Nation, & Rosen, 2005; Poelmans et al., 2011; Robertson, Joanisse, Desroches, & Ng, 2009; Ziegler, Pech-Georgel, George, & Lorenzi, 2009) with subsequent underspecified phonological representations as evidenced by difficulties with processing phonological information (e.g., phonological/phonemic awareness) for word recognition (Castiglioni-Spalton & Ehri, 2003; Goswami et al., 2002; Lonigan, Burgess, Anthony, & Barker, 1998). These challenges can affect all areas of academic achievement, including the ability to read fluently and ultimately comprehend text (Wolf & Katzir-Cohen, 2001).

Importantly, many children with language and reading impairments have more difficulty with the representation of phonological information presented in noise than when presented in a quiet environment (Bradlow, Kraus, & Hayes, 2003; Snowling, 2000). A number of studies have shown that children with language and reading deficits are less accurate than children who are typically developing at repeating words or sentences when presented in noise (Boets, Ghesquière, van Wieringen, & Wouters, 2007; Boets et al., 2011; Fraser et al., 2010; Robertson et al., 2009; Vandewalle, Boets, Ghesquiere, & Zink, 2012; Ziegler et al., 2009). Vandewalle et al. (2012) measured speech perception in noise for monosyllabic words with a group of school-aged children who had both language and reading impairments. Their findings showed that these children scored significantly poorer than those who were typically developing when tested in noise; however, there was no significant difference between the groups when tested in quiet. These findings are consistent with other investigations and suggest that evaluation of speech perception in the presence of noise is more sensitive to the listening problems these children may experience (Bradlow et al., 2003; Vandewalle et al., 2012; Wible, Nicol, & Kraus, 2002). Listening in the presence of a degraded speech signal over time can be expected to interfere with language development and learning, including reading achievement. Children need to be able to perceive speech clearly in the classroom while learning to map speech sounds onto letters during the development of early reading skills (Ziegler et al., 2009).

Research has not substantiated these findings in all children with language and reading disorders. A number of studies have found that groups of children with language and reading disorders exhibit no problems with speech perception, suggesting that there are subgroups within this population (e.g., Marshall, Ramus, & van der Leyly, 2011; Ramus, 2003). The differences found in the literature may reflect the heterogeneity of this population, with children demonstrating individual variations in specific deficit areas (Bailey, Manis, Pederson, & Seidenberg, 2004; Bishop & McArthur, 2005; Marshall et al., 2011; Joanisse et al., 2000; Peterson, Pennington, & Olson, 2013). The diversity in speech perception performance found in this group makes it all the more crucial to discover the best ways to evaluate children with reading difficulties who seem to find listening a challenge. Clinicians may find that measuring speech recognition in the classroom directly will assist in identifying the individual listening needs of a particular child so that classroom accommodations and intervention strategies may be designed to provide the most benefit.

The effect of classroom acoustics on the learning of children with normal hearing who have special listening needs has received a growing amount of attention from speech/language and hearing professionals in recent years (ASHA, 2002a, 2005; Coalition for Classroom Acoustics, 1998; Crandell, Smaldino, & Flexer, 1995; Nelson & Soli, 2000). The reduction in access to the intrinsic redundancy of spoken language that occurs in adverse listening conditions (e.g., with noise, distance, and reverberation) potentially leads to decreased speech understanding for school age children in a variety of groups, including those with auditory processing disorders (APD), articulation/language disorders, learning disabilities, and those learning English as a second language (Crandell et al., 1995). Indeed, it has been suggested that all children younger than 13 years are less likely than older students or adults to understand speech well in noisy and/or reverberant conditions (Crandell & Smaldino, 2000; Elliott, 1982; Elliott et al., 1979; Klatte, Lachmann & Meis, 2010; Nabalek & Pickett, 1974; Yacullo & Hawkins, 1987). The youngest school-age children tend to be at the greatest disadvantage; for example, Jamieson and colleagues (Jamieson, Kranjc, Yu, & Hodgetts, 2004) demonstrated that kindergarteners and first graders performed significantly worse than second and third graders in understanding single words with different syllable patterns at a signal-to-noise ratio of -6 dB using noise recorded from a typical classroom. Children in these groups with special listening needs who have poorer perception of speech in noise and/or reverberation than peers with typical development would be considered at risk for academic difficulties.

Because of the widespread prevalence of poor classroom listening conditions, speech/language pathologists and audiologists have proposed that children in these diverse groups might benefit from classroom modifications that include adaptation of the physical environment to reduce noise and reverberation levels, compensatory strategies that ensure accurate reception of instruction material, and/or the use of hearing assistive technology (HAT) to increase signal-to-noise ratio (Flexer, Millin, & Brown, 1990; Flexer, Biley, Hinkley, Harkema, & Holcomb, 2002; Johnston, John, Kreisman, Hall, & Crandell, 2009: Massie & Dillon, 2006; Purdy, Smart, Baily, & Sharma, 2009; Rosenberg et al, 1999; Sharma, Purdy, & Kelly, 2012). Improving the signal-to-noise ratio and signal clarity in the classroom would be particularly important for children in the early grades because of their greater difficulty with speech perception in noise overall and the importance of establishing foundational concepts and skills for later development. Rosenberg and colleagues (1999) reported faster progress in listening and learning behaviors and skills in classrooms using sound (field) distribution systems over a 12-week period when compared to grade-matched students in unamplified classrooms. Greater benefit was shown for younger children, who had the most to gain—first graders demonstrated lower scores on the teacher rating scales than older students before the use of amplification. A higher proportion (30.88%) of the first graders in the Rosenberg et al. (1999) study was receiving special education services. A more recent investigation (Dockrell & Shield, 2012) failed to show significant gains on academic tests after six months use of sound distribution technology in a general elementary school sample; however, students in the amplified classrooms who had special educational needs did show significant improvements in academic test scores when compared with their counterparts in classrooms without sound distribution. A number of studies have indicated a significant increase in literacy skills, particularly in the areas of phonological awareness and reading comprehension, associated with the use of classroom sound distribution systems (Darai, 2000; Flexer et al., 2002; Heeney, 2007). Purdy and colleagues (2009) showed improved teacher and student ratings of classroom listening following a six-week trial use of personal frequency modulation (FM) systems at school in a group of elementary school children with reading delays; however, no significant effect of FM system use was found on scores of standardized reading tests. The authors concluded that a longer period of FM system use may be necessary to show improvement in reading test scores.

The application of HAT in the classroom, originally developed for use with children with hearing impairment, is becoming more commonplace in special school age populations with normal hearing sensitivity. The most recent clinical practice guidelines from the American Academy of Audiology (2008) in the area of remote microphone hearing assistance technologies for children specifies "children and youth with normal hearing sensitivity who have special listening requirements" (p. 5) as one of three listener groups who are potential candidates for some sort of remote microphone hearing technology. The guidelines further list these subgroups: English language learners and children with auditory processing deficits, learning disabilities, language deficits, and/or attention deficits. HAT arrangements recommended for children with normal hearing are either personal FM systems with FM-only ear level, body, or desktop receivers or sound distribution systems that amplify the speech signal and deliver it throughout the classroom through loudspeakers installed on the walls or ceilings (AAA, 2008; Kreisman & Crandell, 2002). The recommendation of HAT for children in this population should be considered on an individual basis, using appropriate measures to determine the need for HAT and to validate the use of the particular technology selected (ASHA, 2002b, 2005, Rosenberg, 2002). Special emphasis should also be placed on assessing the classroom listening environment to ensure the best possible academic outcome (Johnson, 2010). Environmental modifications complement the use of HAT, help enhance acoustic access to speech, and facilitate learning through the auditory mode. If HAT is desired or recommended, the educational audiologist would be the most qualified professional to evaluate the need for HAT, to dispense it and monitor use, and to measure outcomes with HAT in the classroom. The question arises if functional measures typically used to justify and validate the use of HAT for children with hearing loss will be applicable to groups of children with normal hearing who show special listening needs.

The Functional Listening Evaluation (FLE; Johnson & VonAlmen, 1997) was designed to assess speech recognition in school age children with hearing impairment under conditions simulating a typical classroom. By testing speech recognition across various conditions, the clinician examines how noise, distance and visual input may affect a child's understanding of speech in the classroom setting. The FLE is commonly used by educational audiologists to determine situational effects on speech understanding, to provide evidence for the need of HAT, to validate the use of HAT, or any combination thereof (Anderson & Smaldino, 2012; Johnson, 2010; Lewis, 2010). In designing an individual education program (IEP) for a child with hearing loss, the FLE has been suggested to fulfill IDEA's requirement of an "evaluation of the needs of a child with a disability, including a functional evaluation of the child in the child's customary environment" (Assistive Technology 34FR300.6 [Part B]). The FLE has been recommended as particularly useful to assess children with minimal/mild losses and those with auditory processing disorders (Lewis, 2012; Haider, 2009) whose deficits in speech perception in noise tend to be more subtle than those of children with moderate to profound degrees of hearing loss.

The FLE has a number of advantages in assessing classroom listening. Speech recognition performance is measured directly, resulting in quantifiable data. The percent correct scores yielded by the FLE may be subject to less examiner bias than teacher rating scales. Relatively objective, quantifiable measures are valued in justifying intervention strategies, especially when recommending that a school district purchase hearing assistive technology for a particular classroom or child. The FLE protocol is flexible; a number of variables can be adapted depending on the purpose of assessment and the situation of the particular child. Ideally, the FLE is conducted in the child's own classroom (or a comparable one) when it is unoccupied. The fact that the assessment takes place in a classroom setting and simulates typical conditions provides some ecological validity when compared to speech recognition testing in the audiological booth. Additionally, the decision matrix allows the examiner to evaluate the effects of noise, distance, and visual input on speech understanding, making it easier to align recommendations to assessment data. The FLE was developed for use with children who have hearing loss; however, it might also be a useful clinical tool in evaluating children with language and reading impairments, but normal hearing. The FLE could potentially assist in documenting situational listening difficulties in this population and in providing evidence for need of auditory-based interventions, including HAT.

Though it is recommended often as a functional assessment tool (AAA, 2008; Anderson & Smaldino, 2012; Elkayam, 2008; Johnson, 2010), the clinical effectiveness of the FLE has not been evaluated thoroughly in the literature. There is no research that documents the FLE performance of children with normal hearing who are typically developing. Data are also limited regarding its use with children who have special listening needs, but normal hearing. To date, no study has examined the value of using the FLE in children with language and reading impairments to evaluate the potential need for classroom accommodations and/or assistive technology.

The purpose of the current study was to answer the following questions:

1) Does the FLE show reduced sentence recognition in the presence of background noise, distance, and/or lack of visual cues in children with reading difficulties but normal hearing?
2) Does the FLE demonstrate poorer speech recognition performance in children who are judged by parents to have listening problems when compared to children who are judged by parents to have no significant listening difficulties?
3) Are children's ratings of listening difficulty associated with their sentence recognition scores?

Methods

Participants

The participants were selected from attendees of a university-sponsored language and literacy program, an intensive month-long day camp held in the summer; the activities are focused on improving language and literacy skills. The total number of participants was 41: 28 males and 13 females. Children were between the ages of 7 and 10;11 (years; months) inclusive. All children passed a bilateral hearing screening at 1000, 2000, and 4000 Hz at 20 dB HL. All children were diagnosed with oral and written language disorders related to literacy by certified, licensed speech-language pathologists associated with the university clinic. Informed parental consent was obtained for each participant after approval from the university Institutional Review Board. Each participant was paid twenty dollars.

Due to the expectation that the participants would vary widely in perceptual abilities, the group of children with reading difficulties was further subdivided using the Fisher's Auditory Problem Checklist (Fisher, 1985). This checklist is used commonly in schools to assess auditory areas of concern for children with hearing loss and/or to determine whether students with normal hearing sensitivity require further assessment of auditory processing (Emanuel, 2002). The intent in using the Fisher's was not to screen for (nor to diagnose) auditory processing disorder, but to quantify parental observations of listening ability and to identify a subgroup of children with reported listening difficulties.

The Fisher's Checklist is designed as a teacher or parent questionnaire. It has 25 behavioral target items, and the parent checks each behavior that is observed in the child. The score is derived from the percentage of unchecked items; a higher percentage indicates better function and less need for evaluation. It takes little time to complete and has a clear recommendation of a cut-off score to determine the need for further evaluation. The suggested criterion for referring a child for further assessment is a score of 72 percent. In the current study, parents completed the Fisher's Checklist and returned it to the principal investigators with the consent form. Children with scores equal to or less than 72% were assigned to Group 1 (Listening Difficulty, n=22), and children with scores greater than 72% were assigned to Group 2 (No Listening Difficulty, n=19). Group 1 had a mean age of 8;10, and the mean age for Group 2 was 9;1, with no significant difference in mean age between the groups. The examiners who administered the FLE were blind to the Fisher's score and group classification of each child.

Procedure

The FLE was administered by two undergraduate student researchers in an unoccupied classroom in the same building in which the day camp was taking place. Training and supervision of the student researchers were provided by a licensed, certified audiologist. The FLE protocol (2002 revision of Johnson & Von Almen, 1997) was used. Each child was asked to repeat short sentences (Standard American English version of the BKB sentences; Bench, Koval & Bamford, 1979, Kenworthy, Klee, & Tharpe, 1990) presented in eight different listening conditions (see set-up in Figure 1; for list of conditions and sequence see Table 1). The BKB/SAE sentences have simple structure and a vocabulary appropriate for use with children with normal hearing as young as five years of age (Johnson, Benson, & Seaton, 1997). Each sentence was presented only once. There are eight BKB sentence lists, with 50 target words per list; children are scored by the percentage of key words repeated correctly. The order of the sentence lists was counterbalanced, but the sequence of the listening conditions was kept the same as was recommended in the FLE protocol.

The student researchers worked in pairs; one examiner presented the sentences using monitored live voice while the other sat near the child and recorded the child's responses. All children in the study were intelligible; some children showed articulation errors, most commonly distortion or substitution of another phoneme for /r/. Any articulation errors were treated so as not to influence scoring; that is, words with consonant substitutions or distortions were not counted incorrect if the child consistently showed the substitution/distortion throughout the session. For example, if a child who consistently substituted /w/ for /r/ said /wæn/ for 'ran', the word was counted correct. The examiners alternated roles with every other child. Each participant wore a wireless lapel microphone during the testing session, which transmitted his/her voice to a digital recorder; responses were recorded, digitized and saved as a sound file to refer to for any questions about scoring and to establish inter-observer reliability. The level of sentence presentation (average of 75 dBA SPL) was monitored using a sound level meter (Larson-Davis DSP80) placed one foot away from the speaker's mouth. The sound level

Table 1. Sequence of Listening Conditions in the FLE

Order	Condition	Abbreviation
1	Auditory-Visual Close Quiet	AVCQ
2	Auditory Close Quiet	ACQ
3	Auditory-Visual Close Noise	AVCN
4	Auditory Close Noise	ACN
5	Auditory-Visual Distant Noise	AVDN
6	Auditory Distant Noise	ADN
7	Auditory Distant Quiet	ADQ
8	Auditory-Visual Distant Quiet	AVDQ

meter was calibrated before each test session. During the 'Noise' conditions, a recording of multi-talker babble was used; the volume was adjusted so that the noise level averaged 60 dBA SPL at the child's ear. During the 'Auditory only' conditions, a screen made of acoustically transparent material prevented view of the speaker's face. The child was seated in a desk, and the examiner stood three feet from the child in the 'Close' conditions and moved to 15 feet away in the 'Distant' conditions. Immediately following the presentation of each sentence list, the participants were asked to rate the difficulty of the listening task on a 5 point scale (1 = very easy, 5 = very difficult), and each child's rating was recorded on the score sheet.

Inter-observer reliability was measured for the sentence recognition scores (key word scoring). A graduate student in speech-language pathology listened to the recorded sessions of 20% of the participants selected randomly by patient number and determined scores for each condition. There were two children from this subsample who were noted to have consistent articulation errors (mostly /r/ errors); this was similar proportionally to the children with sound distortions/substitutions in the overall sample. These scores were compared to those of the original examiners. The correlation between observer scores was .92 collapsed across conditions, ranging from .87 to .99. The recordings were also used to re-evaluate the FLE for all participants (n=39, one child in each group had missing recordings) using a verbatim scoring strategy. In verbatim scoring, the scores were based on the percent of sentences rather than key words correctly repeated, and the sentences had to be repeated exactly as the examiner presented them to be judged correct. Articulation errors were taken into consideration as described above.

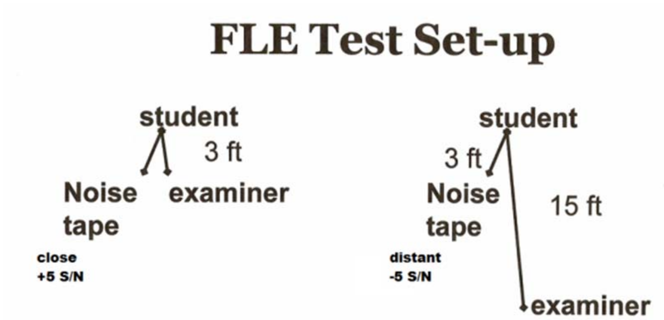

Figure 1. Physical set-up of the FLE test environment. Adapted from the 2002 revision of "The Functional Listening Evaluation" by C. D. Johnson and P. VonAlmen. Retrieved from http://www.handsandvoices.org/articles/education/ed/func_listening_eval.html. Copyright 2005 by Hands and Voices. Reprinted with permission.

Results

Fisher's Auditory Problems Checklist

The mean score for Group 1 (Listening Difficulty, LD) was 53% (SD 16%), and the mean score for Group 2 (No Listening Difficulty, NLD) was 82% (SD 5.6%). The mean score for Group 1 was just above the 50.4% score reported to represent two standard deviations below the normative mean for all age groups. The range of scores for Group 1 was 8% to 72%. The mean score for Group 2 was slightly below the normative means for 7- to 11- year olds (ranging from 85.6 to 87.4%), but scores ranged from 76% to 92%, all within one standard deviation of the normative group mean for all ages (68.6%). Scores on the Fisher's Auditory Problem Checklist were not correlated with age.

Table 2. Key Word Scoring: Mean Percent Correct by Parental Rating Group

Group	AVCQ	ACQ	AVCN	ACN	AVDN	ADN	ADQ	AVDQ*
LD	96.6	96.5	96.9	97.2	96.2	96.3	96.3	95.5
No LD	98.5	98.1	97.6	98.5	97.5	96.3	97.9	98.4

Note. LD = rated by parents as having listening difficulty; No LD = rated by parents as not having listening difficulty. * p < .05, one-tailed

Table 3. Verbatim Scoring: Mean Percent Correct by Parental Rating Group

Group	AVCQ	ACQ	AVCN	ACN*	AVDN	ADN	ADQ*	AVDQ*
LD	86.9	87.8	87.5	83.9	85.7	82.1	84.2	82.4
No LD	92.4	93.1	90.6	92.7	88.9	87.9	90.6	93.1

Note. LD = rated by parents as having listening difficulty; No LD = rated by parents as not having listening difficulty; * p < .05, one-tailed

Functional Listening Evaluation

When using key-word scoring, speech recognition scores for the FLE were high overall. The mean percent correct scores for the entire sample are shown in Table 2. No child scored below 80% under any condition. There were 50 target words in each sentence list; no child missed more than 10 words in any condition. Mean percent scores did not vary across the eight listening conditions. There was no significant correlation between age and percent correct under any condition. Children with listening difficulties demonstrated slightly lower mean recognition scores for every condition; however, mean scores for Group 1 were still high, ranging from 95.5 to 97.2%. A series of *t*-tests for independent samples demonstrated a significant difference between groups only for the last condition: Auditory-Visual/Distant/Quiet (AVDQ). Group 1 showed greater variability in speech recognition scores in all conditions; only children in Group 1 had scores that were lower than 2 standard deviations below the mean for the entire sample.

When using the more stringent verbatim scoring, the mean recognition scores decreased for both groups across all conditions (see Table 3). Group 1 scores decreased by a greater extent than Group 2 scores for all conditions. The AVDQ condition (Auditory-Visual/Distant/Quiet) showed the greatest difference between the groups for mean percent correct. The *t*-tests for independent samples showed that the between-group difference in mean number of sentences missed was significant ($p < .05$) for the AVDQ, ADQ (Auditory-only/Distant/Quiet), and ACN (Auditory-only/Close/Noise) conditions, with Group 1 missing more sentences. The variability within both groups increased using verbatim scoring, though the maximum score for all conditions was 100% for each group. Both groups demonstrated the lowest mean score for the most difficult condition, ADN (Auditory-Only/Distant/ Noise). There was no correlation between age and percent correct under any condition. As expected, the key-word scores for each condition were correlated significantly with the verbatim scores for the same condition (correlations ranged from .66 to .89).

The FLE scoring includes an interpretation matrix that averages performance across the different conditions to allow the examiner to determine effects of the three variables (noise level, distance, or presence of visual cues) on speech recognition. The mean scores (based on verbatim scoring) for each group averaged across the relevant conditions are shown in Table 4. Several *t*-tests for dependent samples were performed; a statistically significant difference was present in the mean number of sentences missed between the quiet conditions and the noise conditions for Group 2 (higher number of sentences missed in noise), but not for Group 1. Means did not differ for either group between Auditory-Visual conditions in comparison to Auditory-only conditions. A significantly higher number of sentences was missed by both groups in distant conditions relative to close conditions.

Table 4. Verbatim Scoring: Interpretation Matrix for Mean Percent Score by Parental Rating Group

Group	Quiet %	Noise %	Close %	Distant %	Auditory-Visual %	Auditory Only %
LD	85.5	84.8	86.5	83.6 *	85.6	84.5
No LD	92.3	90.0 *	92.2	90.1 *	91.2	91.1

Note. LD = rated by parents as having listening difficulty; No LD = rated by parents as not having listening difficulty. Significant differences shown between conditions (Quiet vs. Noise, Close vs. Distant).
* p < .05, one-tailed

Perception of Listening Difficulty

The mean rating of listening difficulty ranged from 1.2 (AVDQ) to 2.26 (ADN) for the entire sample. Individual ratings of 4 and 5 (greatest difficulty) occurred primarily for conditions with noise. Overall, children's rating of listening difficulty was correlated to percent correct only in the close, quiet conditions (r = -0.45, -0.39). The same trend was evident when using verbatim scoring. The two groups did not differ in their mean ratings across the conditions. The conditions in order of perceived difficulty (easiest to most difficult) are shown in Table 5. The conditions were ranked according to the mean listening difficulty ratings for the whole sample. The quiet conditions are ranked 1-4 (easier) and the conditions with noise are ranked 5-8 (more difficult).

Table 5. Mean difficulty for FLE conditions as ranked by participants

Condition	Mean Rating
AVDQ	1.2
AVCQ	1.6
ADQ	1.7
ACQ	1.8
AVCN	2.0
AVDN	2.1
ACN	2.2
ADN	2.3

Note. Conditions were rated by participants across the entire sample.
A higher number indicates a listening condition rated as more difficult.

Discussion

Functional Listening Evaluation

Key word scoring. The present study used the FLE to determine whether children with reading difficulties showed reduced speech recognition in the presence of noise, increased distance from the speaker, or lack of visual cues. The BKB/SAE sentences were selected to prevent vocabulary level or complex sentence structure from contributing to the participants' speech recognition performance. Using conventional key word scoring of the BKB/SAE sentences, the scores were notably high for the entire sample of children across the eight listening conditions.

The lowest score for an individual child under any condition was 80%. Mean speech recognition scores were above 95% for all conditions. There was limited variability, but age did not contribute to the children's performance under any condition. The reduced performance range and high scores suggest that with key word scoring of the BKB sentences, the FLE as conducted in this study was a relatively easy task for the 7- to 10-year-old children with reading difficulties, but normal hearing. Use of sentence material to measure speech recognition provided semantic and syntactic context to assist with key word identification. The BKB/SAE sentences were used by Lewis and coworkers (Lewis, Hoover, Choi, & Stelmachowicz, 2010) as one measure of speech perception in noise. Scoring sentences correct only if all three key words were correct, they still encountered ceiling effects at a +5 signal-to-noise ratio for 5- to 7-year-old children who were typically developing. Even at 0 dB signal-to-noise ratio, mean scores for the 5-year-olds were above 80%. Clearly, more difficult speech material should be used for any elementary school age population with normal hearing to discover potential perceptual deficits in noise. Bradlow and coworkers (2003) suggested that children with reading impairments may depend more on context than their typically-developing peers, so the use of children's nonsense phrases might provide a more challenging task for this group, with an appropriate vocabulary level but without syntactic or semantic cues to the identity of key words.

An important difference between the FLE protocol and some procedures reported in the literature is that the FLE task is set up so that there is spatial separation between the source of the signal and the noise source (see Figure 1). In numerous studies showing marked speech-perception-in-noise deficits for children in special populations, recorded speech stimuli are mixed with noise and delivered via earphones or a loudspeaker in front of the child (e.g., Bradlow et al., 2003; Crandell & Smaldino, 1996). Thus, the signal is embedded in noise and both are coming from the same direction. Speech perception in this condition is a more difficult task than understanding speech when the interfering noise is spatially separated from the signal source (Cameron, Dillon, & Newall, 2006; Johnstone & Litovsky, 2006). This may explain in part why children in this study showed relatively high speech recognition scores even in disadvantageous conditions. The FLE's orientation of the noise source and signal source is likely more representative of conditions in classrooms where most noise sources surround the students and typically do not come from behind the teacher.

The Fisher's Auditory Problem Checklist was used to identify a subgroup of children with listening difficulties based on conclusions drawn from parental observation. We were interested in whether the FLE would reveal differences between the LD and no LD groups. Interestingly, the parental responses divided the total sample of children with language and reading impairments into two roughly equal groups (22 in Group 1, LD, and 19 in Group 2, No LD) using the suggested 72% cut-off score. The mean age of Group 1 was slightly lower than that of Group 2; this was not a significant difference, nor were there correlations between age and any of the measures. There were proportionally more males in Group 1 (77% versus 58% in Group 2). The FLE as conducted in this study was largely insensitive to differences between children with and without listening difficulties when using the conventional key word scoring of the BKB sentence materials. Though the LD group showed significantly lower mean scores than the no LD group for the last condition in the sequence, Auditory Visual/ Distant/ Quiet (AVDQ), the effect size was small; in addition, mean scores were above 95% for both groups.

Verbatim scoring. Rescoring the FLE using a stricter verbatim scoring strategy generally reduced scores and yielded greater variability. Using the more rigorous verbatim scoring seemed to affect Group 1 (LD) to a greater extent than Group 2 (no LD), resulting in more evident differences between the two groups. The variability within Group 1 was always greater than for Group 2, regardless of condition. This trend was also apparent for key word scoring, but to a lesser extent. The poorest scores for the entire sample in each condition were always from children in the listening difficulty (LD) group; maximum scores of 100% for each condition were obtained for participants in both groups. Though mean sentence recognition scores were lower for the LD group in all conditions, only three conditions showed statistically significant between-group differences: Auditory/Close/Noise (ACN), Auditory/Distant/Quiet (ADQ), and Auditory-Visual/ Distant/Quiet (AVDQ). The ACN condition is the most acoustically difficult of the close conditions (noise added, no visual cues). The ADQ and AVDQ conditions, while less acoustically rigorous due to lack of noise, may have been more difficult for the LD group because they were the last two tested in the FLE sequence. Both the LD and no LD groups showed their poorest performance overall in the ADN (Auditory/Distant/Noise) condition, with means of 82.1% and 87.9% for Group 1 (LD) and Group 2 (no LD), respectively. The mean scores for Group 2 improved for the two noiseless conditions following ADN (ADQ and AVDQ), as would be expected for comparable conditions in quiet, while mean scores for Group 1 (LD) did not change appreciably for the last two quiet conditions when compared to ADN. The entire FLE protocol took between 25 and 40 minutes for each child; there may have been effects of reduced attention or fatigue in Group 1 that decreased performance somewhat for the last two quiet conditions in the sequence. In other words, the children with listening difficulties may have been expending greater effort on the FLE than those without; they may not have been able to sustain the same level of attention over time, which could have reduced their performance in the later conditions, confounding the effect of acoustic difficulty. Further research on the effect of condition sequence would be helpful to determine whether potential order effects exist.

The FLE interpretation matrix compares scores averaged across conditions to evaluate the variables of noise, distance, and visual input. When evaluating group means averaged across conditions, there was a significant effect of distance for both groups of children (LD and no LD); not surprisingly, scores were poorer in the distant conditions compared to the close conditions. Given that the distant conditions are intended to establish a less desirable signal-to-noise ratio because of the decreased signal level at 15 feet, it is somewhat surprising that only Group 2 (No LD) showed a significant noise effect when compared to the children's performance under quiet conditions. As noted above, Group 1 means were significantly lower than Group 2 means for the last two conditions in the FLE sequence, both in quiet. This may have depressed the LD group's averaged scores in quiet conditions enough to eliminate any significant difference between the conditions with and without noise, especially since the effect size is so small (approximately 2-3 point differences in group mean scores between conditions). Thus, the lack of a significant noise effect in the LD group may be due to the effects of fatigue or reduced attention on the last two quiet conditions. When averaging across conditions, the absence of visual cues did not affect speech recognition for either group.

Our study, consistent with past work, showed the poorest sentence recognition performance for children in both groups occurred in the Auditory/Distant/Noise condition; this condition provided the lowest signal-to-noise ratio (distance of 15 feet decreased the signal level, multi-talker noise present). Thus, children with language and reading impairments, with or without reported listening difficulties, were least accurate at recognizing speech when the signal-to-noise ratio was lowest (approximately -5 dB). The condition that distinguished most between the LD group and the no LD group (that is, where the difference between group means was the largest) was also a distant condition: Auditory Visual/Distant/Quiet. Though designated a 'Quiet' condition, there is always ambient classroom noise, which, combined with the lower signal level at the child's ear in the distant condition, may produce a less than ideal signal-to-noise ratio. On the average, children in the no LD group were able to take advantage of visual cues or the lack of multi-talker noise to achieve better speech recognition in the AVDQ condition than in the more difficult ADN condition, while the children in the LD group were not. Children without reported listening difficulties (Group 2) may have been more attentive to visual and auditory cues available in this condition. They may have been less affected by the lower signal level in the absence of the moderate levels of multi-talker competing noise. An ability to understand speech at a distance increases the likelihood that incidental learning will occur. For example, a child who overhears the teacher answering another child's question may not have to ask for clarification herself. As suggested before, since AVDQ is the last condition in the FLE sequence, children in the LD group may have been less attentive due to fatigue at maintaining the effort needed to listen, resulting in poorer performance. In this study, the FLE was administered after the child had attended the day camp where they participated in three hours of language and reading intervention. If children in the LD group were experiencing fatigue towards the end of the FLE, their ratings of listening difficulty might be expected to rise for the last condition, but this was not the case, nor did their mean rating differ from the no LD group in any condition. This may suggest that children in the LD group were not aware of errors they were making. Further research determining how acoustic environment and task demands interact to challenge children with special listening needs may help clarify these results.

Regardless of the reason, the FLE indicated that greater distance and decreased signal-to-noise ratio increased the difficulty of the speech recognition task in this clinical population, particularly for children with reported listening difficulties. A teacher with numerous children with special listening needs in the same classroom may find it difficult to give preferential seating to all to reduce distance effects. The teacher location within the room that may be advantageous for listening for some children may be disadvantageous for others. Even teachers who effectively manage the room's noise level on a consistent basis will not be able to provide an ideal signal-to-noise ratio for all students at all times, nor can they control variables, such as transient or fluctuating hearing loss related to middle-ear disorders that may be present intermittently in some children who already have listening difficulties. Remote microphone HAT is designed especially to alleviate these types of classroom challenges. Sound distribution systems increase the signal-to-noise ratio for all children in the classroom by amplifying the teacher's voice level and work particularly well in classrooms that are not overly reverberant. Personal FM systems provide the highest signal-to-noise ratio possible for individual children who require especially favorable conditions for optimal speech perception. In addition to the speech recognition benefits, the use of classroom HAT may provide other advantages: maintaining students' attention to the teacher's voice, decreasing off-task time, allowing teachers to talk and convey a calm attitude (without having to raise their voices to be heard), increasing opportunities for incidental learning, and decreasing the amount of effort students use to listen, freeing up cognitive and energy resources for higher-level thinking (Heeney, 2007).

Perception of Listening Difficulty. The groups had similar mean ratings of self-perceived listening difficulty across the FLE conditions. The presence of noise seemed to dominate perceived listening difficulty (see Table 5), with the four quiet conditions ranked as easier than the four noise conditions. Children's perception of listening difficulty did not correlate with percent correct scores regardless of scoring strategy except weakly in the close, quiet conditions. This finding is consistent with results from Klatte and colleagues (2010), who found that first and third graders' 'disturbance ratings' of noisy and reverberant conditions were very low (signifying no or little disturbance to listening) and did not correlate with their speech recognition or listening comprehension performance, which was severely affected by the most difficult conditions. On the other hand, considering the relatively high percentage scores for key word recognition overall, low mean ratings (indicating easy conditions) may have accurately represented the difficulty of the listening task overall for this sample of children. Exploring how well children are able to judge the effect of difficult classroom listening conditions on their speech recognition is important because children who do not perceive that they are having difficulty will not know to ask for help or clarification. They may not realize that they misunderstood what the teacher or other students said until they are called upon to respond or use the information in some other way. Further study of whether listening difficulty ratings are associated with acoustic conditions is warranted in this population in situations with a greater range of difficulty.

Study Limitations

Results from the FLE can be used to support the recommendation of HAT use in the classroom for children with listening difficulties. With this in mind, FLE data from a control group of age-matched, typically developing children with normal hearing would have been useful. Evidence that children with language and reading impairments (or other special listening needs) perform significantly poorer in adverse listening conditions than their typically developing classmates is needed to justify the provision of HAT by schools. Data from a control group also might clarify for this age group and speech material what scores would represent a significant reduction in speech recognition in various conditions in comparison to typically developing peers. The FLE is meant to be adapted to the specific classroom environment of the individual child being evaluated, and interpretation of the FLE results for a particular child places emphasis on the effect of the conditions (i.e., noise, distance, absence of visual cues) on the child's speech recognition rather than a comparison of the child's performance to normative values. Even so, FLE data for typically-developing children with normal hearing would help clinicians evaluate the magnitude of speech recognition deficits in clinical populations as well as the amount of benefit gained by the use of HAT.

In recognition of the heterogeneity of this study's participants despite the common diagnosis, the Fisher's Auditory Problems Checklist was used to designate a subgroup with listening difficulties within the clinical population of interest. The Fisher's Checklist was selected in part because it takes little time to complete and has a clear recommendation of a cut-off score to determine the need for further evaluation. Defining the subgroup with listening difficulties based solely on parental responses to the Fisher's Auditory Problems Checklist may limit interpretation of this investigation's results. Parent perceptions are subjective, and the Fisher's Checklist and other similar questionnaires have been demonstrated to be ineffective at predicting a diagnosis of APD. Questionnaire results have also been shown to be poorly correlated with performance on individual tests of auditory processing (Dawes, Bishop, Sirimanna, & Bamiou, 2008; Wilson et al., 2011). Additional measures, such as standardized, recorded speech-in-noise tests performed in a sound-treated booth, could have been used to support the parent ratings in identifying a subgroup of children who consistently show difficulty with speech recognition in unfavorable listening situations. In the current study, the Fisher's Auditory Problems Checklist was considered to be a functional measure used to describe ongoing problems related to listening rather than a screening tool or diagnostic test for a particular disorder.

Studies comparing speech perception in noise for children in special populations to that of typically developing children tend to be conducted in a sound-treated environment. Differences between experimental and control groups are typically greater in the most adverse listening conditions—for example, the lowest signal-to-noise ratios. Bradlow and coworkers (2003) compared speech perception for children with and without learning disabilities using the BKB sentences at two different signal-to-noise ratios. Children in the current study (entire sample) performed better in the FLE's most difficult listening condition (ADN, Auditory/Distant/Noise) than either group in the Bradlow et al. study did at the most comparable condition: female talker using clear speech with speech level at 65 dB SPL and noise adjusted to a -4 dB signal-to-noise ratio. In the ADN condition of the FLE, the noise level is kept constant at 60 dBA at the child's ear, and the signal level is expected to drop with distance to provide a signal-to-noise ratio of approximately -5 dB. Though each examiner monitored her level of presentation using a sound level meter mounted a foot away, the dB SPL of the examiner's voice was not measured at the ear of the listener. It is possible that a -5 dB signal-to-noise ratio was not achieved; that is, that the children were experiencing a somewhat higher signal-to-noise ratio, making the distant task easier than expected. The most recent version of the FLE (revised 2011 by Johnson, available at http://successforkidswithhearingloss.com/wp-content/uploads/2011/08/FLE-2011_autocalculate_saveable2.pdf) recommends confirming that the examiner's voice is at 65 dBA SPL at the listener's ear with the examiner standing in the close condition at a distance of three feet rather than extrapolating from a measurement made closer to the examiner. In future research on the FLE, both the signal and the noise level should be verified at the child's ear.

Conclusions/Clinical Implications

Children with language and reading impairments are among numerous groups of individuals with normal hearing who may benefit from the use of hearing assistive technology in the classroom (AAA, 2008; Crandell & Smaldino, 2000). The FLE is often used to provide a rationale for HAT use in the classroom for children with hearing loss, and might also be useful for the same purpose when evaluating children like the participants in the current investigation. The FLE, as conducted in this study, was largely insensitive to differences between children with and without listening difficulties (based on parental responses to the Fisher's Auditory Problems Checklist) when using the conventional key word scoring of the BKB sentence materials. The fact that rescoring responses with a more rigorous criterion resulted in greater variability and demonstrated larger differences between the two subgroups and between conditions suggests that modifying some of the parameters of the FLE to create more demanding listening tasks would potentially increase its value for use with children who have normal hearing, but special listening needs. In particular, the use of speech material with no syntactic context (e.g., Children's Nonsense Phrases [Johnson, Benson, & Seaton, 1997]) and lowering the signal level would increase the difficulty of the speech recognition task across the conditions. These changes also might increase the sensitivity of the FLE to potential speech recognition problems of individual children with language and reading impairments. Testing solely the auditory-only conditions (i.e., omitting the auditory-visual conditions) is an option to reduce the test time unless examining the effect of visual cues is relevant for a particular child. Further study is needed to determine what combination of modifications of the FLE would result in conditions that adequately tax children with normal hearing without using unrealistically low signal-to-noise ratios that do not represent typical classroom environments. Investigating the effect of using speech materials varying in length, complexity and amount of context may also be productive when assessing children with language and reading impairments.

With an increasing emphasis on improving classroom acoustics for children with normal hearing who are at risk academically, educational audiologists and speech-language pathologists will be challenged to identify which children will benefit the most from classroom interventions that increase access to speech. The FLE is a standardized but flexible clinical protocol that can indicate what classroom conditions might have a negative effect so reception of information in the classroom can be facilitated as much as possible. The FLE matrix form isolates the effects of distance, noise, and absence of visual cues; it can be helpful to justify the recommendation of particular accommodations (e.g, preferential seating, preservation of visual cues, noise reduction, HAT use to counteract noise and distance effects). Future research should focus on what modifications of the FLE would provide the most useful information to support professional recommendations and also examine the effectiveness of the FLE in measuring outcomes with hearing assistive technology in this population.

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Audiologists on the Literacy Team: A Natural Fit

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Recent research indicates that pediatric and educational audiologists do not discuss literacy development with families. Although there are a variety of reasons for this, overall it appears that audiologists perceive they lack the necessary background and therefore are not qualified to discuss reading, even though preliminary reading skills (phonological awareness) are auditory based. In terms of overall expertise, we defer to reading specialists, but as members of a child's intervention team, we can do more. In our role as hearing/listening experts, it is certainly within our scope of practice to help families recognize that learning to read effectively starts at birth, with consistent access to speech sounds and active thinking about those sounds. These auditory experiences are necessary to prepare a child's brain to associate sounds to letters.

If we currently do not feel qualified to discuss these relationships between hearing, listening, and reading, what would help us grow into this expertise? The following pilot project describes how, with brief training and a few hours of direct intervention, Au.D. students increased their competency in the domain of phonological awareness to the point where they were able to explain and apply the hearing-listening-reading relationship accurately and also assume a sense of professional responsibility toward literacy development. This report concludes with suggestions on establishing a working knowledge of literacy development as a logical extension of our pediatric practices, and applying that knowledge to our settings.

Introduction

Even in this era of early detection and intervention, children with impaired hearing are at risk of developing reading problems (Moeller, Tomblin, Yoshinaga-Itano, Connor, & Jerger, 2007; Robinson, 2009). The reasons are multi-faceted, but at least one likely reason is that families need more support from *all* intervention team members, including audiologists, in the development of reading skills. What is the audiologist's contribution? Because learning to read is typically an auditory-based process, and audiologists are experts in audition, we can legitimately assume a role on the "literacy team" by helping families better understand the connection between hearing, listening, and reading.

The Hearing-Listening-Reading Connection

Although there is more than one way to learn to read, most children learn by associating sounds with symbols (e.g., the symbol **B** makes the sound /b/). To make these associations, children must first become very nimble listeners, developing a skill set based on thousands of hours of practice. In fact, children need about 20,000 hours (5- 6 years of a child's waking hours) of incessant listening, plus paying attention to/thinking about the differences and similarities in speech sounds (phonemic awareness), before they are able to master their first reading lesson (Cunningham, Cunningham, Hoffman, & Yopp, 1998; Luckner & Handley, 2008; Nielsen & Luetke-Stahlmann, 2002).

During these thousands of hours, neural pathways establish hard-wired connections from the temporal lobe to the rest of the brain. These connections are essential: when a child learns to associate a letter to a sound, the occipital lobe processes the visual signal as the temporal lobes process the characteristics of the auditory signal, and the hippocampus retrieves memories of the sound (Dehaene, 2009). Without these neural connections, the relationship between the sound and the letter lacks meaning and is not learned.

Educators providing early reading instruction expect children to be ready to make these sound-symbol associations by the time they start kindergarten. In the U.S., each state's Department of Education defines expectations for specific skills for specific ages, including pre-kindergarten. As one example, the Ohio Department

Table 1. Pre-Kindergarten Reading Standards re: Phonological Awareness (Ohio Department of Education, 2011)

Phonological Awareness
- Demonstrate understanding of spoken words, syllables, and speech sounds (phonemes)
- Recognize and produce rhyming words
- Using hearing to isolate the syllables of a word by snapping, clapping, or rhythmic movement (e.g., cat, ap-ple)
- Recognize when words share phonemes (sounds) and repeat the common phoneme (e.g., /b/ as in Bob, ball, baby; /t/ as in Matt, kite, boat)
- Differentiate between sounds that are the same and different (environmental sounds, animal sounds, rhyming sounds)

of Education (2011) published pre-reading standards for children not yet enrolled in kindergarten. In order to be fully prepared for kindergarten instruction, children are expected to have mastered some fairly sophisticated listening skills, described in Table 1.

These standards are not unique to one state; readers will find very similar evidence-based standards in their own states as well. The website education.com has links to all state Departments of Education (http://www.education.com/reference/article/Ref_edu_table/). To find standards specific to literacy, use the following keywords to search: reading; literacy; communication arts.

Our Role on the Literacy Team

There is much we do not know. We do not know if families are aware of these school expectations. We do not know, as they contend with the daily challenge of optimal amplification, if they are encouraged to look ahead, to prepare their children for their first reading lesson by helping them listen for 20,000 hours. We do not know if they are provided family-appropriate strategies designed to develop phonemic awareness skills, or reinforced as they attempt this important task.

We do know that, if families have made the hearing-listening-reading connection, it is likely due to their own resources, or support from other professionals. Although audiologists may be aware of the hearing-reading-reading connection, we probably do not relay it to parents. A recent survey of audiologists revealed that most respondents reported having little or no background in this area, and therefore do not have discussions with parents or provide materials to help them develop their child's reading skills (English & Snyder, 2010). These data were collected from practitioners in the field and reflect past training.

Are today's audiology students being taught about the hearing-listening-reading connection? Based on textbook review and syllabus review, we can tentatively conclude that the answer is *no*. For instance, the following three well-known textbooks are designed for Au.D. education:

- *Hearing in Children* (5th ed.)(Northern & Downs, 2002),
- *Pediatric Audiology: Diagnosis, Technology, and Management* (Madell & Flexer, 2008), and
- *Comprehensive Handbook of Pediatric Audiology* (Seewald & Tharpe, 2011).

A careful review indicates the first two texts make no mention of literacy development, although the third has two pages on the topic (pp. 768-770)(English, 2011).

Of course, textbooks do not fully inform this discussion because instructors often build their courses on pre-determined learning objectives and then use textbooks to support those objectives. If a course included a learning objective not covered in a textbook, it would be supported with supplemental readings and, more importantly, would be reflected on the course syllabus. A few years ago, a review of 25 syllabi (English & Vargo, 2006) from courses in educational audiology/school-age child management was conducted, and no mention of the hearing-listening-reading connection was found. No review of course syllabi addressing pediatric issues among the birth-to-five population has been published.

Given the ongoing concerns about children's reading skills, it would seem we have an opportunity and an obligation to refine our scope of practice (American Academy of Audiology, 2004) to include the development and application of a working familiarity with literacy development. Of course, before considering change, audiologists will desire evidence to support this logical but infrequently mentioned application of their listening expertise. The following is a report describing a pilot project involving three Audiology Doctoral (Au.D.) students who, with an introductory-level background, provided phonological awareness (PA) lessons to preschoolers with impaired hearing. We wanted to know if this experience yielded a measurable improvement in the Au.D. students' understanding of the hearing-listening-reading connection. Did they conclude that some degree of expertise in literacy development is a "natural fit" for audiologists? The project described below was approved by the University of Akron Institutional Review Board.

Methods

Participants

Participants included the second, third, and fourth authors of this report, who at the time of the project were first and second year Au.D. students. Their participation was voluntary and was based on their expressed interest in the topic of literacy and children with hearing loss.

Materials

Materials included a set of classic children's books (see Table 2) and 24 simple lesson plans adapted from Zongc (2000). Lessons were designed to highlight targeted phonemes presented

Table 2. Books used in PA lessons

Brown Bear, Brown Bear, What Do You See? By Eric Carle
Chicka Chicka Boom Boom by Bill Martin
Five Little Monkeys Jumping on the Bed by Eileen Christelow
Hop On Pop by Dr. Seus
Llama Llama Red Pajama by Anna Dewdney
Pajama Time by Sandra Boynton

in the books, focusing on the pre-literacy skills of rhyming and alliteration. See Appendix A for a sample lesson.

Procedures

Before beginning the project, the Au.D. students received a one-hour tutorial on the relationship between hearing and reading (Wiley & English, 2010) and instructions on conducting their phonological awareness (PA) lessons. They were then assigned to a rotating 12-week schedule to provide PA lessons at a local preschool to three children (ages 3-4) with hearing impairment severities ranging from mild to severe.

Before each session, the Au.D. students conducted listening checks (stethostet, Ling 6 sounds) to confirm functionong of the preschooler's personal and/or classroom amplification devices. The sessions were conducted in a one-on-one format in a quiet room away from the classroom. Lessons were 15 minutes long and were provided twice a week. After each lesson, Au.D. students recorded their observations, communicated with the classroom teacher, and sent a duplicate lesson plan home with the child to keep families informed. At the completion of the 12-week project, each Au.D. student had accumulated six hours of experience delivering PA lessons to preschoolers.

Analysis

After completing the project, the Au.D. students were asked to summarize their experiences by writing responses to the following three questions:

(1) Describe your background re: the relationship between audiology and pre-literacy skills before and after the PA project, using the following rating system:

1 = No background (no awareness of PA)
2 = Novice level (was aware of PA)
3 = Apprentice level (completed formal assignments on PA)
4 = Participant (actively engaged in structured process on PA)
5 = Expert (am qualified to give workshops and write on PA)

(2) Describe any insights ("aha" moments) during and after the project.

(3) Having experienced a learning opportunity that most audiologists do not share, if you were to give a presentation about your activities in the PA project, what would you want audiologists to know?

The results section provides a summary of their responses.

Results

Self-Evaluations

All three Au.D. students rated their initial status as *novice* (level 2). They acknowledged being aware of the topic of phonological awareness (PA) but had no formal background. As one student put it, "I knew very well that a child needs to hear constant input (especially in the critical learning period of the first five years of life) to adequately develop speech and language at a rate similar to that of their normal hearing peers. However, what I feel was not stressed enough is the importance of the relationship between hearing and reading/writing development."

After the project, all three students rated themselves as *active participants* (level 4). Some ways in which they described their "learning curve" include these observations:

> *I feel comfortable and confident now when counseling children and their families on the importance of reading and listening and its influence on the development of literacy and pre-literacy (reading and writing) skills.*
>
> *After this project, I have become an active participant in the process of promoting the relationship between literacy skills and audiology. Since then, I have completed a rotation in the school systems and was provided the opportunity to actively engage in marrying the two concepts, particularly with preschool and elementary students with hearing impairment. I frequently discussed with parents the importance of reading aloud to their child, encouraging the child to participate in the story*.
>
> *In the few short weeks that we were able to participate in this project, I learned so much. The lessons that we were going over became almost second nature*.

The reliability of these self-reports were triangulated (Knudsen et al., 2012) in two ways: after the project, the first author (1) held a one-hour debriefing with the Au.D. students to verify their mastery of the topic and (2) interviewed the classroom teacher, who confirmed the students' knowledge base and competency levels based on her post-session debriefing consultations.

Insights Shared ("Aha" Moments)

It would be expected that getting involved with an unfamiliar topic would lead to insights about the topic and the process. Au.D. students shared these thoughts:

> *The first day that I met with the children was eye-opening to say the least. It was clear from the start that these children were struggling when it came to reading and literacy… It seemed as though their motivation was very low and they were not particularly interested in the activities. As the weeks went by, we had found new ways to deliver the same stories to keep them interesting. The children began to open up and participate. I found myself leaving the school just to sit in my car in the parking lot thinking about all the progress that we seemed to be making. By the end of the project, the child who would hardly speak and almost refused to participate was laughing as we (yes WE) talked about what was happening in the stories*.
>
> *Another "aha" moment was when I figured out what worked to motivate the children to excel. At first, I thought it was essential to do the same routine each day and be in charge the entire time. I was not letting the child make any decisions. What works better is to include the children and ask their thoughts and opinions. As long as I switched things up and wasn't predictable in my agenda, I gained the children's attention and saw improvement. For example, instead of just re-reading the book with the child for a second time, it was more interesting for them to go through the book and pick out words rhymed/started with the same letter (alliteration).*
>
> *The week before our project was to end I asked the teacher what she thought of the students' performance in the classroom since the beginning of the project. She told me that they were completely different kids. She said that they were performing better with in-class activities, were speaking more (and more clearly), and were overall more interested in participating. This description met very closely with what I had observed over those weeks as well.*

What should audiologists know?

From their responses to this question, it appeared the Au.D. students did not find the topic of literacy development a daunting or overly specialized topic, or a topic that exceeds audiology's scope of practice. Rather, their recommendations seem very consistent with typical family counseling. For example, they hoped audiologists would inform families that:

- Early accessibility to individual sounds within words and sound patterns/structure of words can have a positive effect on early reading skills;
- Reading books to children is one of the most effective ways to develop pre-reading/listening skills;
- Ways to get children involved while reading include: having the child repeat back words that rhyme or have alliteration (words that begin with the same or similar consonants); point to the words together; talk about similarities among words; have the child point to pictures in the book that rhyme or start with the same consonant.

Discussion

First, a point of clarification. We do not propose that all Au.D. students replicate this kind of preschool experience. The project required considerable time and external financial support, and was available to only a fraction of the class. However, we do propose that Au.D. students can learn about the relationship between hearing and reading in a relevant course in a reasonable amount of time and be able to explain it to families. The brief preschool experience described here suggests that this is an achievable and relevant learning objective.

As with all pilot studies, this project has inherent limitations, including the small number of participants, the lack of a control group, and the use of a non-standardized self-evaluation tool. With those caveats, however, this pilot project did yield an interesting finding: that a change in self-evaluation from *awareness* to *active engagement* occurred after delivering only six hours of PA instruction. (As an aside, based on regular review meetings, it is the first author's judgment that this degree of competence was more likely reached within 3 hours of experience, and the remaining hours helped solidify confidence levels.)

Like the Au.D. students in this project, many pediatric and educational audiologists would currently describe themselves as *novices* to phonological awareness. We can cautiously conclude, however, that advancing to *active engagement* seems to involve a reasonable time commitment. For Au.D. students, instructors could develop a unit on phonological awareness with a few articles (e.g., Wiley & English, 2010), using role-play or oral exams to verify students' knowledge and skills, and/or enlist the support of SLP faculty who specialize in this area. The unit would recognize our limited but vital role in literacy development: going beyond the fitting of amplification to providing parent-centered rationales for full-time device use. For professionals, a half-day workshop comprised of readings, lecture, demonstration, hands-on experience, feedback would provide the means to obtain the requisite background to qualify as members of the literacy team.

Application of this skill set, of course, is another issue and will depend on the setting. Audiologists who work with toddlers and preschoolers regularly interact with early interventionists and speech-language pathologists; these colleagues would surely welcome our support in their work on PA development. By adding a few relevant questions to the case history, for instance, we convey to families that *all* team members are dedicated to their child's reading future. At the same time, we also learn how much families have absorbed about listening and reading and how far along they are in the commitment to full-time device use.

To support that conversation, the handout in Appendix B was created (Wiley & English, 2012). Audiologists can refer to these developmental milestones to determine if their patients are "on track." Parents can take a copy of this handout to the early interventionist and speech-language pathologist and ask for more help if needed.

Another discussion point should include books. The recurring recommendation from reading experts is to encourage parents to read to their child, ideally 20 minutes every day (Luckner & Handley, 2008; MacDonald & Cornwall, 1995; National Center for Family Literacy, 2009; National Institute of Child Health and Human Development, 2006). As we relay this recommendation, parents might appreciate direction about book titles by age group. There are several creative ways to provide help without using much time, including the suggestion to consult with the local library. Additionally, parent volunteers might be willing to create handouts, provide book reviews for a website, or manage a "take one, bring one back" library.

Audiologists who work with older children have already seen the effect of delayed reading development, and may feel there is nothing to be done at this point. Although some critical windows of learning have passed, it is never too late to learn to listen to a story and then translate those listening skills into reading. Trelease (2006) describes the evidence supporting the academic and cognitive benefits of listening to read-aloud stories and reading out loud to children of all ages. Audiologists can promote these benefits to families and encourage reading to their children for several more years as a way to enhance literacy development.

Conclusion

Pediatric and educational audiologists do not screen for literacy development, primarily because of a lack of background (English & Snyder, 2010). This pilot project suggests that acquiring the background is manageable and is consistent with the "manage the child, not the ears" philosophy to which pediatric and educational audiologists subscribe.

More research is certainly needed, including input from parents. It would be very helpful to know if a focus on reading skills resonates with and inspires parents, perhaps more so than our traditional focus on speech and language. After all, "developing speech and language" is an admittedly vague goal, and probably intimidating to parents, but "developing pre-reading skills" by the first day of kindergarten, as defined by their state's standards, provides a specific deadline and concrete goals that parents can readily manage.

Are audiologists part of the literacy team? The answer is *yes*: we are the "first responders" by fitting amplification, and amplification gives access to literacy. The role is a natural fit for our profession, and the need for our engagement is great. We do have some work to do, of course, to contribute meaningfully to the team effort. In the meantime, new questions at this point include: how will pediatric and educational audiologists incorporate reading development into their professional practices? How will we measure effectiveness, and how will we identify best practices? Where are we going to be on this issue in 5, 10 years? Can't you just hear Carol Flexer? "Tick, tick, tick…"

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Appendix A

Sample Phonological Awareness Lesson

Book: *Brown Bear, Brown Bear, What Do you See?*

Objectives: Print awareness and rhyming recognition

1. Read assigned book with child, pointing to words and the pictures associated with those words.

2. "This book keeps using the same 2 words: ME and SEE. Those words rhyme because they end with the same sound: ee. Let me hear you make that ee sound."

3. "Other words end in ee, too, so they also <u>rhyme</u> with ME and SEE. Listen: words like (have child repeat after you):

He	She	Tree	Key
Key	We	Bee	Three

4. "So, ME and SEE rhyme. Do these words rhyme?" Write in child's answer and provide feedback: confirm when child is correct; clarify if not.

ME and KNEE ______	ME and YOU ______
TREE and BEE _____	HE and HOUSE _____
BEE and BOY ______	SEE and SHE ______

Total Correct: _____

5. "Your turn!" Read book again, leaving last word of each phrase for child to say: Brown bear, brown bear, what do you ________

6. Spend closing minutes talking about the book in general: what's your favorite picture, etc., and remember to read this book with your mom or dad at home tonight.

Appendix B

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For Audiologists: Phonological Awareness Skills Acquisition

Developmental Sequence

Lori Wiley, AuD and Kris English, PhD © 2012

Rhyming	**(Examples: cat, bat, sat, mat)**	
Age	Skill	Date
2-3 years	Participates in nursery rhymes, finger plays, jingles, songs, reading books	
3-5 years	Matches words that rhyme	
4-5 years	Produces words that rhyme	

Alliteration	**(Examples: ball, bounce, bath, bug)**	
Age	Skill	Date
3-5 years	Recognizes words with a common initial sound	
5-7 years	Produces words with a common initial sound	

Blending		
Age	Skill	Date
3-5 years	Combines sequences of isolated *syllables* to produce words (hot-dog; air-plane)	
5-7 years	Combines sequences of isolated *sounds* to produce words (d-o-g; t-r-ee)	

Segmentation		
Age	Skill	Date
3-4 years	Counts number of syllables in words	
4-5 years	Identifies initial sounds in words	
5-6 years	Isolates and pronounces initial, medial, and final sounds in 3-phoneme (CVC) words	

Adapted from Paulson, L.H., & Moats, L. (2010). *LETRS for early childhood educators*. Cambium Learning Sopris West.

http://gozips.uakron.edu/~ke3/AudiologistChecklist2012.pdf

The Pursuit of Technology: Obtaining Classroom Sound Field Amplification Systems in a Rural Setting

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A vast amount of research regarding classroom sound field amplification technology (also called Classroom Audio Distribution Systems – CADS) has resulted in the recognition of benefits to both teachers and students using these systems. Among the many advantages, research has shown that many children, regardless of hearing status, demonstrate improved listening and learning behaviors that enhance the literacy learning of early readers in amplified classrooms (Heeney, 2004; Mainstream Amplification Resource Room Study, 1992). In addition, teachers are able to benefit from improved vocal health and control of classroom behavior (Sapienza, Crandell, & Curtis, 1999; Crandell, Smaldino, & Flexer, 1995; Flexer, 1989; Rubin, Aquino-Russell, & Flagg-Williams, 2007; Eriks-Brophy & Ayukawa, 2000). In spite of these undeniable benefits, many schools still lack this technology. This could be attributed to limited equipment funding as well as the need for educating teachers and administration as to the potential benefits that sound field amplification can provide to everyone in the classroom. In this field report, these two areas of concern were addressed within a rural elementary school system that defined and achieved a goal of classroom amplification systems for all kindergarten through third grade classes. The teachers and administrators were educated as to the benefit that classroom amplification could provide in an effort to garner support for the project. In addition, various avenues of funding resources were explored and subsequently obtained. The defined goal was achieved within two years, in spite of limited funding options available in the rural community. An initial informal survey of teachers showed that they are pleased with the amplification systems and using them consistently.

Introduction

Many audiologists are aware of the published research showing the benefits of sound field amplification devices (also called Classroom Audio Distribution Systems – CADS) in the classroom to young learners as well as their teachers.

Benefit to Students

Various studies have shown improved reading skills, math achievement, and listening behaviors when sound field amplification systems are used in the classroom. For example, Millett and Neil (2010) examined reading outcomes for first grade students in 24 classrooms. Half of the classrooms had amplification and the other half did not. The authors reported that the amplified classrooms had a higher percentage of students reading at grade level over those in unamplified classrooms. In another study, Heeney (2004) observed improvements in amplified classrooms students' listening comprehension, reading comprehension, reading vocabulary, and mathematics over peers in unamplified classrooms in his study, which included students in grades one through six. In a third study, Updike (2006) shared results that documented academic improvement in language and math sections of a standardized state assessment when comparing third grade students who had access to classroom amplification to students from the previous year who did not have this technology. Additionally, the frequently referenced Mainstream Amplification Resource Room Study (MARRS) provides audiologists with data that academic achievement is improved for all students with the use of sound field amplification in classrooms (Mainstream Amplification Resource Room Study, 1992).

Benefit to Teachers

Previous research also suggests that sound field amplification systems provide benefit to teachers in terms of vocal health, reduced muscle tension, and increased behavior management in the classroom. When examining the profession as a whole, teachers have a greater incidence of voice disorders as well as missed work days due to vocal problems over non-teachers (Ray, Merrill, Thibeault, Gray, & Smith, 2004). Several studies showed that when sound field amplification devices were used in the classroom, teachers reduced their vocal loudness, which subsequently led to reduced vocal strain and fatigue resulting in fewer missed work days (Sapienza, Crandell, & Curtis, 1999; Crandell, Smaldino, & Flexer, 1995; Flexer, 1989; Gilman & Danzer, 1989; Edwards, 2005).

The health of teachers as well as the need to keep them in the classroom is important, and yet, classroom amplification can provide benefits to teachers that go beyond these issues. Increased efficiency in the classroom as well as improved student responses to the teacher were documented in research by Rubin, Aquino-

Russell, and Flagg-Williams (2007). In addition, Eriks-Brophy and Ayukawa (2000) conducted a study that found on-task behavior and attending behaviors of students improved in amplified classrooms after just three months of use. Increased student attention as well as improved listening behavior was also noted by Edwards (2005) with the use of sound field amplification systems. In another study, researchers reported that children who have Attention Deficit Hyperactivity Disorder (ADHD) as well as emotional or behavioral related disorders were able to respond more quickly to the teacher when in an amplified versus unamplified classroom (Maag & Anderson, 2006, 2007). Finally, when sound field amplification systems were installed in grades kindergarten through second, the children's inappropriate classroom behaviors decreased (Palmer, 1998). Furthermore, Blair (2006) documented in another study that all teachers using amplification systems in the classroom found them to be useful. These studies show clear support of benefits teachers experience related to improved control of the classroom environment with the use of sound field amplification.

In summary, the aforementioned research studies showed that a better signal-to-noise ratio improved the educational environment for students and teachers. Recently, this research was put into practice when it became a reality for one rural elementary school. This field report will illustrate how creative thinking, education, and the support of the community were required to successfully find and obtain funds for CADS in this rural setting.

Creating an Achievable Goal

It would be ideal to have sound field amplification systems in all classrooms within an elementary school for grades kindergarten through six as the MARRS study supports the benefit of classroom amplification for all children under the age of 15. However, after reviewing the research and assessing the feasibility of this objective, a specific, defined, and achievable short-term goal was formed. The method of implementing evidenced-based practice helped the small group of parents and teachers formulate the school's goal as follows: provide sound field amplification to all classrooms grades kindergarten through three in order to support and enhance the educational environment of early readers and their teachers. This goal was formulated in the fall of 2009 and was designed to support the school's focus of improved reading comprehension and achievement in state test scores related to enhanced literacy.

Methods and Results

The School

The targeted elementary school for this project had approximately 500 students enrolled in grades kindergarten through six, and 45% of these students qualified for free or reduced lunch. This enabled the school to provide programs through Title 1 federal funding, such as supplemental resources for reading and tutoring. Given the financial need of this population, asking students' families for additional funds to support the expense of classroom amplification systems would not likely yield fruitful results. In addition, outside funding sources were limited in this agricultural and manufacturing area.

Step 1: Fostering Excitement Through Education

The first step in meeting this goal of sound field amplification systems in all elementary classrooms from kindergarten through at least third grade began with gaining the support of the administration, the teachers, and the parent-teacher council. Each grade level in this particular school had three classrooms; therefore, 12 amplification systems would be needed to complete the defined goal. Unless all parties were supportive and also excited by this project, progress would not be made. Therefore, contact was made with teachers who had used amplification systems in the past. One teacher was so supportive of this initiative that she was willing to demonstrate her system during formal presentations to the administration and the parent-teacher council. Incorporating a live demonstration of the benefit of this technology was also supported in the literature as an example of one method for educating and sharing the enhancement that is provided to the listening environment when the signal-to-noise ratio is improved (Ostergren, 2006).

The demonstration of the device was highly effective as compared to a simple, informative session with verbal and written facts and figures regarding the benefits of the systems. As the teacher shared her personal experience with this system, she turned on the amplification, and in every instance, there was an audible gasp as the audience witnessed the impressive change in acoustics provided by this system. This powerful demonstration changed the tone of the presentation from one of general agreement and support to one of excitement and need for these devices in the school. The teachers, administration, and parent-teacher council came together with a new understanding and appreciation of these systems that would create the best listening and learning environment for students.

Step 2: The Funding Struggle

Once the support and excitement of the administration was obtained, the next step was to identify potential funding sources and to obtain monies to support this venture. This particular portion of the mission was addressed in several ways:

Parent-Teacher Council. The parent-teacher council took ownership of this sound field amplification project and began setting fundraiser monies aside for the purchase of these systems. The fundraising activities included the sale of trash bags in the fall and spring semesters, a fall carnival, food sales, a restaurant partnership (i.e., receipt of a percentage of profits from 2 to 3 hour time period on a specified date), and a spring bingo game.

The shift in expenditures of their funds resulted in a significant financial contribution toward this project, but it would take many years before the goal of having a system in every classroom could be met. At the same time, the involvement of the parent-teacher council provided an avenue through which grant applications could be submitted. An organization applying for a grant would be more powerful and effective than an individual.

Philanthropic Organizations. Several philanthropic organizations in the community were identified as potential contributors to this project: Psi Iota Xi, Tri Kappa, Lion's Club, and Rotary. Other communities may also have access to Sertoma, Optimists Club, or other benefactors with missions designed to improve education, assist children, support literacy, and enhance speech and language development. Applications to these types of organizations vary, and presentations, such as the demonstration described earlier, can be powerful in garnering financial support for the project.

Private Industry Grants. Often, local hospitals, auto manufacturers, and utility companies offer grants to community-based organizations in support of various projects. Unfortunately, the school and parent-teacher council were disqualified from many local, company-based grants because of the tax related status [501(c)(3)].

Community-Based Grants. Many communities have funds identified as 'Community Foundation' or 'Community Improvement' in which qualification for grant monies vary, but may not exclude school based projects. The site DonorsChoose.org is a web-based option for sharing a project idea, which provides donors the opportunity to contribute to a cause. Fortunately for this project, the Attica Community Foundation (part of the West Central Indiana Community Foundation) did not eliminate the school or parent-teacher council based on the tax status. After completing the grant, attending a meeting to answer questions, and providing resources supporting the need for the project, funds in the amount of $3,600 were awarded from this foundation. This funding allowed for the purchase of four classroom amplification systems. Again, the opportunity to educate the members of these groups was invaluable because the message of creating the best listening and learning environment for the children in this community was received and then acted upon.

As a requirement of the awarded grant, announcements were made to the local newspapers and the school newsletter. These brief announcements shared the news of the grant award, included a picture of the teachers with the equipment, and shared quotes from the teachers relaying their appreciation of the award monies. The Attica Community Foundation was thanked for their support of this important project and for providing the improved listening and learning environment for students. In addition, a summary report detailing the expenditures and successes of the project was provided to the Attica Community Foundation.

Step 3: System Installations & Teacher Surveys

Funding was obtained to purchase and install all twelve classroom amplification systems in grades kindergarten through three. During and following the installation period, several steps were taken to ensure consistent use of the systems. First, teachers were provided with information early in the process regarding the benefits of the amplification systems. The importance of educating teachers regarding the value of these systems was also supported in the literature (Blair, 2006). Second, there was a great deal of initial excitement about receiving the equipment, which was produced through the device demonstrations. These two factors increased the likelihood of continued use of the sound field amplification; however, even minor concerns regarding device use were alleviated once teachers had the opportunity to utilize the amplification systems.

After the systems were used for at least one semester, an informal follow-up survey (provided in the Appendix) was created and provided to the teachers in the 12 classrooms. The goal of the subjective questionnaire was to ascertain any changes in student behavior that may be attributed to the installation of the amplification systems. The intention was to share the information that was gathered with the grant organization, school administration, and neighboring school districts.

Nine of the 12 surveys were returned and seven were complete. kindergarten through third grade teachers were represented in these seven surveys, and the seven classrooms represented a total of 138 students (i.e., 17 to 22 students per room). According to the survey, attention and behavioral issues were identified in 24 of these 138 students (~17% of students). The seven classrooms were all of comparable size (approximately 50'x 50') and had carpet, ceiling panels, and blinds over the windows. No other sound-dampening strategies or devices were in place.

On the seven completed surveys, all teachers agreed or strongly agreed that, since installation of the equipment, students were better able to maintain attention during a lesson and throughout the day. Additionally, five of the seven teachers agreed or strongly agreed that students were quieter since the sound systems were installed, and four of the seven reported that students were able to follow verbal instructions the first time they were given (Figure 1). The information obtained from the surveys was subjective, but did provide insight into the teachers' perceived benefit of the sound systems.

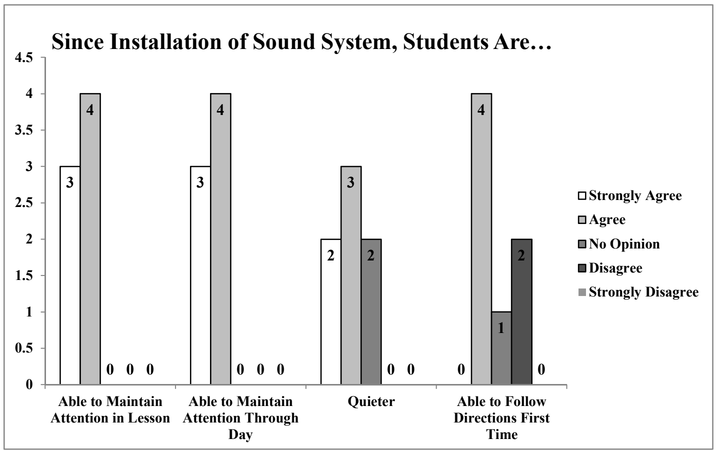

Figure 1. Teacher survey results.

The survey also elicited information regarding teachers' health and revealed that teachers noted reduced vocal strain, muscle fatigue, and headaches after installation of the sound field amplification systems. In addition, teachers generally noted improved classroom behavior, attending and listening behaviors, and felt that the sound field amplification had a positive impact on their classroom. This was notable considering that approximately 17% of the children in these classrooms had attention and behavioral problems (Table 1).

Even before the survey was offered, teachers verbally shared experiences of calmer classrooms, students prompting use of the systems, and less frequent reinstruction and redirection of students throughout the day. Several teachers wrote comments on the survey to share the experiences they had with the equipment (Table 2). The technology was appreciated and continues to be used for all hours of the school day in every classroom that is equipped with amplification.

Table 1. Teachers' Perceptions of the Benefit of Classroom Amplification.

Response	Number Responding
Strongly Agree	5
Agree	2
No Opinion	0
Disagree	0
Strongly Disagree	0

Responses were given to the statement "Based on my knowledge and observations, I believe the amplification system is beneficial to each student's overall attention, listening and learning in the classroom."

Table 2. Additional Teacher Comments from Survey

"The improvement for me in terms of reducing stress has been amazing. I hope I never have to go without one." (referenced vocal stress and tension headaches/muscle fatigue)
"It seems to help my hearing impaired student. The children love it when I speak right in it to get their attention when we interview our friend for classroom book and individual take home Friend Books, they get to wear it and that is 'fun'."
"I love the system. I see a huge difference in the student's attention span and listening skills!"

Discussion and Conclusions

The goal of obtaining sound field amplification in every classroom from kindergarten through third grade was achieved within two years. The community as a whole, the administration, the parent-teacher council, and the Attica Community Foundation should be proud of their efforts and acknowledged for the important roles they played in achieving this impressive accomplishment. Providing classroom amplification was truly a community endeavor and a successful undertaking for this rural location because of the support of many persons and organizations. Sharing the steps that were taken to define and meet the goal of classroom amplification with other audiologists, speech language pathologists, and rural school system administrators will benefit students in other communities.

The teacher survey form that was created and utilized as a post-evaluation measurement of satisfaction with classroom amplification had several limitations. Because of a lack of data prior to installation of the equipment, caution should be exercised in drawing conclusions to the amplification attributing to improved student attention. If this survey were to be used in the future, additional modifications to several questions would also be warranted. With that in mind, the subjective reports of teachers and students suggested that this project was successful and should be expanded to the upper grade levels.

In addition to eliciting verbal feedback and basic survey results from teachers, students in grades kindergarten through two in this school system complete beginning, middle, and end of year reading and math standard assessments. These scores are being monitored for trends regarding academic changes that could be attributed to classroom amplification. Any noted trends will be reported in a future research.

Appendix. Teacher Survey

Sound Field (SF) System Teacher Survey
Developed by: Shannon Van Hyfte, AuD, CCC-A

School:__________________________ Teacher:________________________________

Grade Level: __________________________ Date: ________________________________

Approximately how long have you had your SF equipment? ____________________

What is the approximate size of your classroom? ____________________

Is the classroom carpeted? YES NO

Does the classroom have drapes over the windows? YES NO

Does the classroom have fabric on the walls? YES NO

Are there any other sound dampening items in the classroom? YES NO
If yes, please explain.

How many students are in the classroom? ____________________

How many students have attention/behavioral issues? ____________________

How many students have chronic ear infections/hearing loss? ____________________
How many wear hearing aids? ____________________
How many use personal FM systems? ____________________

How many students function below grade level in reading and/or spelling? ____________________

Have you previously suffered from vocal problems (i.e., loss of voice, laryngitis, hoarseness)? YES NO
If so, how frequently do these problems arise? ____________________

Have you previously suffered from tension headaches or muscle fatigue in your neck or shoulders? YES NO
If so, how frequently do these problems occur? ____________________

1= Strongly Agree 2= Agree 3 = No opinion 4 = Disagree 5 = Strongly Disagree DNA = Does Not Apply

<u>Since installation of the equipment:</u>

Students are able to maintain attention throughout a lesson.

1 2 3 4 5 DNA

Students are able to maintain attention throughout the day.

1 2 3 4 5 DNA

My classroom seems to be quieter.

1 2 3 4 5 DNA

I frequently have to redirect my students in order to keep them on task.

1 2 3 4 5 DNA

My students are able to follow directions the first time they are given.

1 2 3 4 5 DNA

I have vocal problems (i.e. hoarseness, bouts of laryngitis, times of loss of voice).

1 2 3 4 5 DNA

I have headaches/muscle tension (i.e. muscle fatigue in head, neck, or shoulders).

1 2 3 4 5 DNA

Based on my knowledge and observations I believe the amplification system is beneficial to student's overall attention, listening and learning in the classroom.

1 2 3 4 5

Overall, I am satisfied with the sound field amplification system in my classroom.

1 2 3 4 5

Please add comments to help us understand any benefits or lack of benefits received from this equipment. Any specific data you have regarding changes in student grades would help us assess long-term benefit of the equipment. One example might be an average class grade in reading prior to installation of the sound field equipment compared to the average class grade after 3 months of installation. Additional comments:

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2013 Journal of Educational Audiology

The Journal of Educational Audiology is now soliciting manuscripts for the 2013 issue (Volume 19). All submissions will be peer-reviewed and blind. JEA publishes original manuscripts from a range of authors who work with children and their families in a broad variety of audiological settings. One of the primary purposes of the Journal is to provide a forum to share clinical expertise that is unique or innovative and of interest to other educational audiologists. Our traditional focus has been the auditory assessment, management, and treatment of children in educational settings. However, contributors are not limited to those who work in school settings. We invite authors from parent-infant and early intervention programs, as well as clinicians who work with children in related capacities (e.g. Clinical Pediatric Audiologists, Speech-Language Pathologists, Auditory-Verbal Therapists). As the only audiology journal dedicated to a pediatric population, the intent is to reflect the broad spectrum of issues relevant to the education and development of children with auditory dysfunction (e.g. children with hearing loss, auditory neuropathy/ dys-synchrony, or central auditory processing disorders).

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**NOTE: Submissions for the 2013 issue of JEA will be accepted until July 31, 2013. Manuscripts received after that date will be considered for the 2014 issue, unless the authors are notified otherwise.*

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A Publication of the Educational Audiology Association

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All manuscripts must follow the style specified in the Publication Manual of the American Psychological Association (6th edition). Authors should pay special attention to APA style for tables, figures, and references. Any manuscript not following the 6th edition format will not be reviewed.

2. Cover Letter

A cover letter should accompany all submissions. The cover letter should contain a statement that the manuscript has not been published previously and is not currently submitted elsewhere. If IRB approval was needed by the sponsoring institution, a statement to that effect should also be included.

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The author information page should include the title of the article, complete authors' names, and authors' affiliations. This page should include a business address, phone number, and email address for the corresponding author.

4. Title Page

This page should contain only the title of the article. No other identifying information should be present.

5. Abstract

The second manuscript page (behind the title page) should contain an abstract not to exceed 250 words.

6. Text

The text of the manuscript should begin on page 3.

7. Tables, Figures, and Other Graphics

Tables, figures, and other graphics should be attached on separate pages and their placement within the manuscript noted (e.g., <<Table 1 here>>). These separate pages should appear after the text and before the acknowledgements.

8. Acknowledgements

Acknowledgements should appear on a separate page after the tables, figures, and graphs and before the references.

9. References

All references should follow APA manual guidelines, as noted above. References are to be listed alphabetically, then chronologically. Journal names should be spelled out and italicized, along with volume number. Authors should consult the APA style manual (6th ed.) for the specifics on citing references within the text, as well as in the reference list. All citations in the text need to be listed in the References.

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What is EAA?
The Educational Audiology Association (EAA) is an international professional organization for audiologists who specialize in the management of hearing and hearing impairment within the educational environment. EAA was established in 1984 to advocate for educational audiologists and the students they serve. The American Academy of Audiology (AAA) and the American Speech-Language-Hearing Association (ASHA) recognize EAA as a related professional organization (RPO), which facilitates direct communication and provides a forum for EAA issues between EAA, AAA, ASHA, and other RPOs. Through the efforts of the EAA executive board and individual members, the association responds to issues and concerns which shape our profession.

EAA Mission Statement:
The Educational Audiology Association is an international organization of audiologists and related professionals who deliver a full spectrum of hearing services to all children, particularly those in educational settings.

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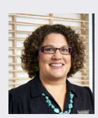

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